AFOEHL REPORT 90-225SA00111MXX

Automation of a Large Analytical Chemistry Laboratory

THOMAS C. THOMAS

December 1990

Final Report

AF Occupational and Environmental Health Laboratory (AFSC)
Human Systems Division
Brooks Air Force Base, Texas 78235-5501

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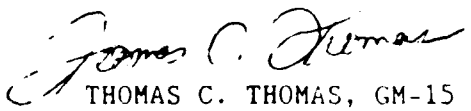

THOMAS C. THOMAS, GM-15
Chief, Analytical Services Division

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This report is based on a paper on laboratory automation which was presented by Mr Thomas at the Southeast-Southwest Combined American Chemical Society in New Orleans, 6 Dec 1990. The report discusses one of the largest laboratory automation programs in the nation. Factors that stimulate laboratory automation are investigated. Advantages of automation in a large laboratory are looked at. Examples of benefits from this automation are displayed in the report.

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Laboratory Automation Automated Samplers LAS Automation Robotic Preparation System LABSAM Automated Network System Thomas

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CONTENTS

ILLUSTRATIONS

I. INTRODUCTION

At some point in their existence, every laboratory must face the possibility of automating some facet of their operation. There are many factors that stimulate automation in laboratories. The workload becomes so large that the laboratory has to accept automation in order to provide responsive analyses. This is coupled with sample holding times, if these holding times are not met, the results provided are not valid. Every laboratory fights a shortage of well-trained personnel and automation can overcome part of this continuing problem. Of course, it is well-known how automation can help in areas like laboratory administration, processing of data, generation of statistical information, printing out results and better communication with customers. Other factors include: safety considerations, lack of funds to contract out overload samples, and an abundance of funds to purchase automated analytical equipment.

Our laboratory has faced all these factors and is on line to totally automate our operations. In fact, we are very close to total automation. The purpose of this report will be to show some of our approaches to laboratory automation to laboratories that are entering this area or are considering entering it. Then, they will have a better insight into the possibilities and problems of laboratory automation.

II. FACTORS STIMULATING LABORATORY AUTOMATION

There are many factors that our laboratory encountered that stimulated laboratory automation.

A. Samples and Analyses Requests: This is probably the biggest factor in causing laboratories to consider some sort of automation. If they don't, their business will eventually be affected as analysis turnaround times increase. An unresponsive result is probably as bad as no result at all. Many problems in the field need timely analytical response to solve the problems, and many regulatory agencies require monitoring results within specific time periods. Failure to provide timely results here can become expensive to the customer and eventually to the laboratory.

Such was the case with our laboratory. Our workload increased drastically over the past 12 years (Appendix A). The samples received more than doubled during this period, while the analyses required on these samples increased by

a factor of almost four. Of course, the many new occupational health and environmental laws and regulations were the cause. In addition, analytical methodologies became more complex and the number of required analytes was increased. As illustrated in Appendix A, the average analyses requested almost doubled. This was due to new analytical methods, such as EPA 601, 608, 625, where a long list of analytes are required. Our laboratory was forced to turn to automation, such as automating sample control; automating sample data entry and result print out; use of robotic preparation and automatic samplers; and instrument control by a laboratory automation system.

B. Sample Holding Time Requirements: Sample holding time requirements go along with the newer laws and regulations and definitely put additional strain on laboratories. Combined with larger workloads, this definitely stimulates labs to consider some form of laboratory automation. What especially hurts is that these sample holding times are counted from time of collection. If samples have to be shipped to a lab, there is even less time remaining for the analyses.

Our laboratory serves worldwide Air Force installations and therefore comes up against these sample holding time requirements. Appendix B shows some of the holding times we have to meet. They range from 1 day to 6 months. With samples coming in from all over the world, the time remaining on them puts a strain on us, especially samples with a holding time of 14 days or less. To meet the requirements, we have had to turn to automated controlled instruments and automated sampler systems, which can be analyzing samples unattended, even after hours and on weekends, if needed.

C. Shortage of Personnel: One of the constant problems of a laboratory is a shortage of well-trained personnel. People with the necessary scientific background are getting harder to find, which makes competition for good chemists and technicians very fierce. It is a common occurrence for these good people to be lured away by another organization for an increase in salary or an advancement in responsibility. Many of the newer methodologies are more complex and definitely more involved. The same staff that handled a certain amount of work 10 years ago are strained to handle the same workload today. There never seems to be enough people to get the samples analyzed in a timely manner.

Such is the case at our laboratory. Coupled with the difficulty of finding good scientists and losing people to

other organizations is the bureaucratic red tape of the government personnel system. Along with this goes hiring freezes, low pay, and difficulty in getting promotions. Appendix C shows the current staff in the Analytical Chemistry Division at our laboratory. This is not nearly enough people to handle this year's projected workload of 85,000 samples and 400,000 analyses. Many of our people are newer scientists and still in a training mode. Therefore, we have had to turn to automated systems like robotic sample preparation systems and automated analyzers. One chemist or technician can have several of these systems going at one time. Even with these systems, it is still a strain to provide timely analyses; therefore, we contract out about 15% of our workload.

D. Shortage of Contracting Funds: One option of handling large workloads or surges of samples is to find an additional source of help. Contracts can be developed with another lab and we have used this approach for some time. When overloads or surges come, the contractor can be analyzing a batch, while our lab is working on a batch. The net result is that timely analyses can be provided in this way. However, as seen from a sample contract task in Appendix D, these analyses can get quite expensive. From our experiences, the range of analysis costs runs from $10 to $2,000 per sample. Our average cost per sample has been around $120. So, for a large group of samples, this approach can be quite expensive. Therefore, our lab has turned to automation to offset part of the costs of contracting. We have found that a mixture of the two works best for us.

E. Available Investment Equipment Funds: One positive influence that favors automation is the availability of funds to purchase the latest in automated equipment. Although this is definitely not the case in most labs, such was the case in our lab. Even though budget tightening and hiring freezes were predominant, in the last three years our lab received great support in the purchasing of investment equipment. As illustrated in Appendix E, in the last three years we purchased $1,638,000 worth of equipment. Some were new purchases, others were to replace outdated equipment. In addition to these updates to our current laboratory automation system, we purchased automated analytical equipment with the latest state of the art capability to tie into our current system. Examples are gas chromatographs with robotic samplers, a continuous flow analyzer system that could perform six inorganic analyses at once, and an automated total organic carbon analyzer in waters. Equipment like this greatly helps in keeping up with our heavy workload and providing timely responses.

F. Administrative Requirements: Even if a laboratory could keep up with a large workload and provide timely analyses, it would hopelessly flood the administrative staff under a sea of paperwork. Can you imagine the large administrative staff that would be required to type up the chemist's reports on our analyses, make copies to send to the customers, copies for other parties, copies for the files, look up requests for overdue or past results, etc. Breakdowns in this area would cause severe problems and is another stimulant for automation.

Such was the case for our laboratory until we automated sample log in, production of worksheets, sample log out, automatic printing of multiple copies of results, storage of results and quick recall of sample status or of past results. Appendix F shows an example of results that are automatically printed.

G. Safety Considerations: I know what you're thinking: "What does safety considerations have to do with being a factor for stimulation of automation?" We probably would have asked that question also if we had not found out through actual use that automation has some safety considerations in it. We found the use of automated equipment is not only advantageous for speeding up analyses, handling tedious and time consuming procedures, and working through nonoffice hours, but for reducing safety exposures and risks to the analysts.

Examples of such equipment in our laboratory include robotic processing systems and automatic sampling processors on gas chromatographic, high pressure liquid chromatographic, and metal analyzers. Inhalation and possible skin exposures to dangerous solvents, acids and metals used in analyses are reduced and even eliminated through use of these systems.

H. Better Communication with Customers/Contract Labs: One stimulant towards acquiring automation is the innovative approaches that can be attempted with it. For example, the laboratory sample management system that logs in our samples has also been programmed to automatically print out sample receipt notices to the customer (Appendix G). This helps the customer know that we received the samples and are analyzing them. Also, it cuts down on the number of sample status inquiries that we get.

Another approach is to tie in the contract labs to our automation system. The contract lab is equipped with a modem system and provided training, so that on overload samples that they are analyzing, they can transmit results

directly into our laboratory sample management system. This speeds up analysis times and eliminates our data entry people from having to manually enter contract lab data into our automated system.

I. Efficient Use of Equipment: Much of the analytical instrumentation available on the market today has been built with automation in mind. This should stimulate laboratories to make full use of automation opportunities. For example, our lab selected new gas chromatographs, ion chromatographs, HPLCs, etc., that would easily tie in with our in-house laboratory automation system. Our robotic preparation systems were designed to interface with the robotic samplers systems on many of our analytical instruments. We selected an automated sample data entry system (a sample form optical mark reader) that would dump its data into our current laboratory automated sample management system. All these systems are tied together, making for the most efficient use of laboratory analytical equipment.

III. THE AFOEHL AUTOMATION NETWORK SYSTEM

The laboratory automation network at AFOEHL/SA is composed of four separate, but integrated components. They are the Laboratory Automation System, Laboratory Sample Analysis Management System, Automated Analytical Instrumentation, and Automated Sample Data Entry.

A. Laboratory Sample Analysis Management System: The Laboratory Sample Analysis Management System (LABSAM) functions mainly by handling samples between the customer/analyst interface. This can be seen in Appendix H. Samples arrive at AFOEHL/SA and are processed by sample control personnel. Data entry personnel enter information about the sample, such as what analyses are needed, which base the sample is from, when was the sample collected/received, what is the base sample identification number, what is the AFOEHL number assigned, etc. All this information goes into the sample management database (LABSAM). A "Field Notice" is automatically generated by LABSAM and is mailed the next day (see Appendix G). It lets the customer know that the sample has been received and processed and approximately how long the analyses will take.

LABSAM sorts out all samples received during the day and automatically generates specific worksheets for Function analyses. It sends this worksheet information to the terminal used by the analysts who will analyze the samples. Sample control delivers the samples to the analysts on the next day. These worksheets have been

designed by the chemists and breaks out the work by specific analysis or for a group of analytes (Appendix I). This helps the analysts in several ways. First, it organizes the work for them, so that they know exactly what analyses are needed. In the past, they would have to manually sort through all the sample request paperwork. Secondly, it provides a worksheet, where instrument readings and results can be entered. These worksheets can then be passed on to data entry personnel who enter the results into LABSAM. The worksheets can then be stored for several weeks in case questions arise on the analysis.

LABSAM automatically determines when all the analyses are completed on a sample and prints out the results during the evening (Appendix F). A three-copy form of the results are printed with the lead chemist's signature block. Early the next morning these final reports are delivered to the lead chemists for their review and signature. One copy is sent to the customer, one copy is available to be sent to other reviewers of the results, and one copy is filed as back-up to the LABSAM storage. Notice that LABSAM automatically prints the date collected, received, analyzed and reported. These dates are required by many states in which our AF bases are located.

The analysts are also trained to access LABSAM's database. This is needed, as the analysts may need to enter some data, check results, or get some detailed information on a sample.

A big advantage of LABSAM is the almost instantaneous generation of almost any type of management data that is needed. The program for requesting it is a user-friendly one. Considering how long it would take to generate this data manually (searching over 100,000 samples now in LABSAM), one can see its value. Examples of four types of management data are shown in Appendix J. As seen in this data, you can ask for the most asked for analytes, total workload by month for the last 10 months, monthly workload and analysis turnaround time for an analysis Function, or number of samples received by each analysis Function and individual Function turnaround times. These are just a few examples of many options. You can see how this information could really be helpful in managing a laboratory.

B. Laboratory Automation System: Our Laboratory Automation System (LAS) is coupled to many of our laboratory instruments as indicated in Appendix K. This instrument controller tells the instruments in which

sequence the samples will be analyzed and the parameters to be used for the analysis. The LAS accepts calibration standards to be used to calculate analysis results. It does this by accepting raw data on samples from the instruments, comparing data such as retention times and calibration data, and prints out all calculations. The LAS controls all analyses on the instruments during off hours and weekends. Data is passed by the LAS to its STATIT software program and statistical data can be generated for the samples run in that batch. Appendix L shows some examples of QC and analysis data which can then be printed. This helps greatly for the various certification requirements that we have.

In some cases, sample results can be passed from LAS to the LABSAM database for storage. At our lab, we have entered this area and are slowly working on the systems to accomplish it. This step is easier said than done and certain problems have to be overcome to accomplish it. Some success has been accomplished.

C. Automated Sample Data Entry System: This area is slowly moving into reality at our laboratory and we are excited about it. It will be tied into our LABSAM system as shown in Appendix K. At the present time, data from the sample submission form are manually entered into LABSAM as shown in Appendix H. This system will use bubble type forms (Appendix M) for AF installations to fill out. The base unit will fill out mailing addresses for results, base sample numbers, date collected, workplace or site identifier, reason for submission, and analyses requested. An optical mark reader automatically reads the sample submission forms and transfers the data to an intermediate PC. The PC at the end of the day, dumps all the data into LABSAM for automatic sample log in. This automation will eliminate most of the manual data entry that is now needed. The equipment is setup and ready to go, the forms are prepared and are now being field tested. After this is completed and with Command approval of these new bubble forms, this operation will become a reality early next year.

IV. CONCLUSIONS

As you have seen, our laboratory is heavily involved in laboratory automation. It is not just a desire, but a must for us. Time for planning, efforts for acquistion, costs of the equipment, and man-hours needed for implementation have been enormous. But, our progress has been very successful. Not all laboratories have our scope of work, and therefore would not need as extensive an automated system as ours. It is my hope that your

laboratory may find some aspect of automating our laboratory and our experiences helpful.

APPENDIX A

SAMPLE AND ANALYSES REQUESTS AT AFOEHL/SA

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INCREASING SAMPLE REQUESTS AT AFOEHL

YEAR	SAMPLES RECEIVED	ANALYSES PERFORMED	AVE ANALYSES PER SAMPLE
1978	39,000	110,000	2.8
1981	50,000	135,000	2.7
1984	65,000	257,000	3.9
1988	77,000	338,000	4.4
1990	85,000(PROJECTED)	400,000(PROJECTED)	4.7

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APPENDIX B

MAXIMUM HOLDING TIMES FOR SAMPLES BEFORE ANALYSES

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MAXIMUM HOLDING TIMES FOR ANALYSES ON WATER SAMPLES

PARAMETER	MAXIMUM ALLOWABLE HOLDING TIME
INORGANICS	2-28 days
PESTICIDES	7 days
POLYNUCLEAR AROMATICS	7 days
POLYCHLORINATED BIPHENYLS	7 days
PHENOLS	7 days
PURGEABLE ORGANICS	14 days
SURFACTANTS	2 days
ORGANIC CARBON	28 days
METALS	6 months
CHROMIUM +6	1 day
CHEMICAL OXYGEN DEMAND	28 DAYS
PRIORITY POLLUTANTS	7 days
OILS & GREASES	28 days

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APPENDIX C

ANALYTICAL SERVICES STAFFING

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ANALYTICAL SERVICES CURRENT STAFF AT AFOEHL

55 PERSONNEL

CHEMISTS - 14 CIVILIAN, 7 MILITARY

TECHNICIANS - 7 CIVILIAN, 17 MILITARY

ADMINISTRATION & MANAGEMENT - 3 CIVILIAN, 4 MILITARY

SUPPORT STAFF - 3 CIVILIAN

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APPENDIX D

COSTS OF CONTRACTING OUT SAMPLES FOR ANALYSES

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F33615-90-D-4004 ORDER: 0007

Item	Description	Method	NR. Ordered	Unit Price	Discount Rate %	Sub Total	Total
1a	Nitrates	E353.2	50	$13.68	9%	$684.	622.44
1a	Total Phos.	E365.4	25	19.00	6	475.	446.50
1a	Alkalinity	E310.1	100	13.68	12	1368.	1203.
1a	Chloride	E325.2	25	13.68	6	342.	321.48
1a	Fluoride	E340.2	25	12.64	6	316.	297.04
1a	Total Dissolved Solids	E160.1	25	10.55	6	263.75	247.95
1a	Sulfate	E375.2	25	12.64	6	316.	297.04
1b	Metals	SW6010	11	156.75	2	1724.25	1689.76
1c	Organochlorine Pesticides and PCB's	E608	50	120.03	9	6001.50	5461.36
1d	Organophos. Pesticides	SW8140	50	115.52	9	5776.	5256.16
1e	Chlorinated Herbicides	SW8150	25	78.85	6	1971.25	1852.97
1f	Volatile Organics	E624	25	234.65	6	5866.25	5514.27
1g	Extractables	E625	25	451.25	6	11281.25	10604.27
1h	Semivolatile Organics	SW8270	12	509.91	2	6118.92	5996.54
1i	Explosives	USATHAMA	11	684.00	2	7524.	7373.52
							$47185.27
2.	Shipping and Mailing						$2814.73
	Total						$50000.00

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APPENDIX E

EQUIPMENT PURCHASES AT AFOEHL

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EQUIPMENT PURCHASES

1988

1- GAS CHROMATOGRAPH
1- FTIR
1- ICP SPECTROMETER
1- GC/MS
1- ATOMIC ABSORPTION SPECTROMETER
1- ION CHROMATOGRAPH
1- TOC ANALYZER
1- POLARIZING MICROSCOPE
1- LOW TEMP ASHER
1- ASBESTOS/MICROSCOPE VIDEO MONITOR
11- EXTRACTOR SYSTEMS

$640K

1989

1- GAS CHROMATOGRAPH
2- HPLC
1- AUTOANALYZER SYSTEM
1- AUTO SAMPLER/GC
5- CHART RECORDERS
1- LARGE GLASSWARE WASHER
MISC ASBESTOS/MICROSCOPE EQUIPMENT
1- PHASE CONTRAST MICROSCOPE
1- CONDUCTANCE METER

$247K

1990

2- HPLC
5- GAS CHROMATOGRAPHS
1- GC/MS
1- CONTINUOUS FLOW ANALYZER SYSTEM
1- LAB AUTOMATION SYSTEM UPGRADE
1- ANALYTICAL BALANCE

$751K

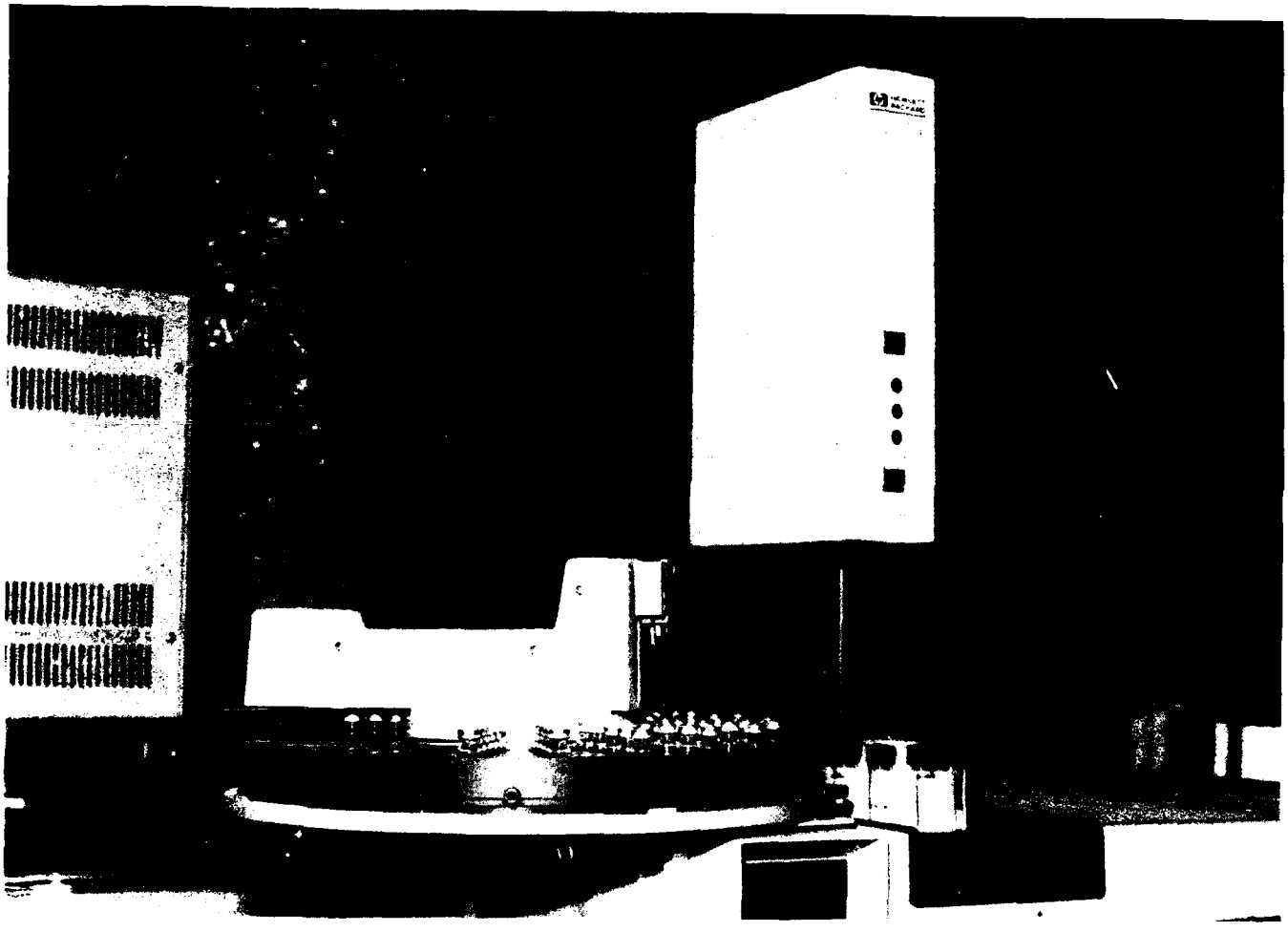

Figure 1. Gas Chromatograph with Robotic Sampler.

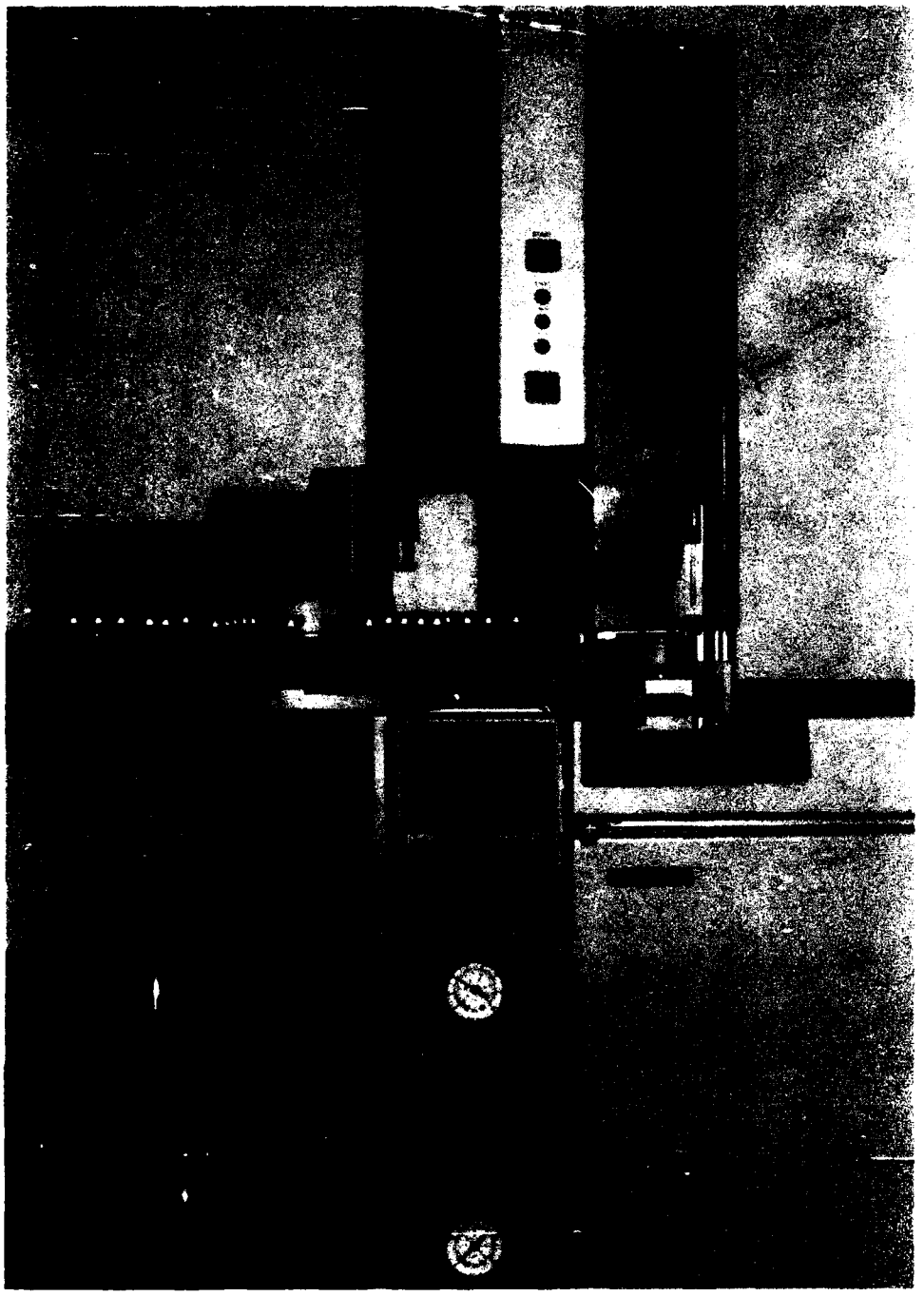

Figure 2. Gas Chromatograph with Robotic Sampler.

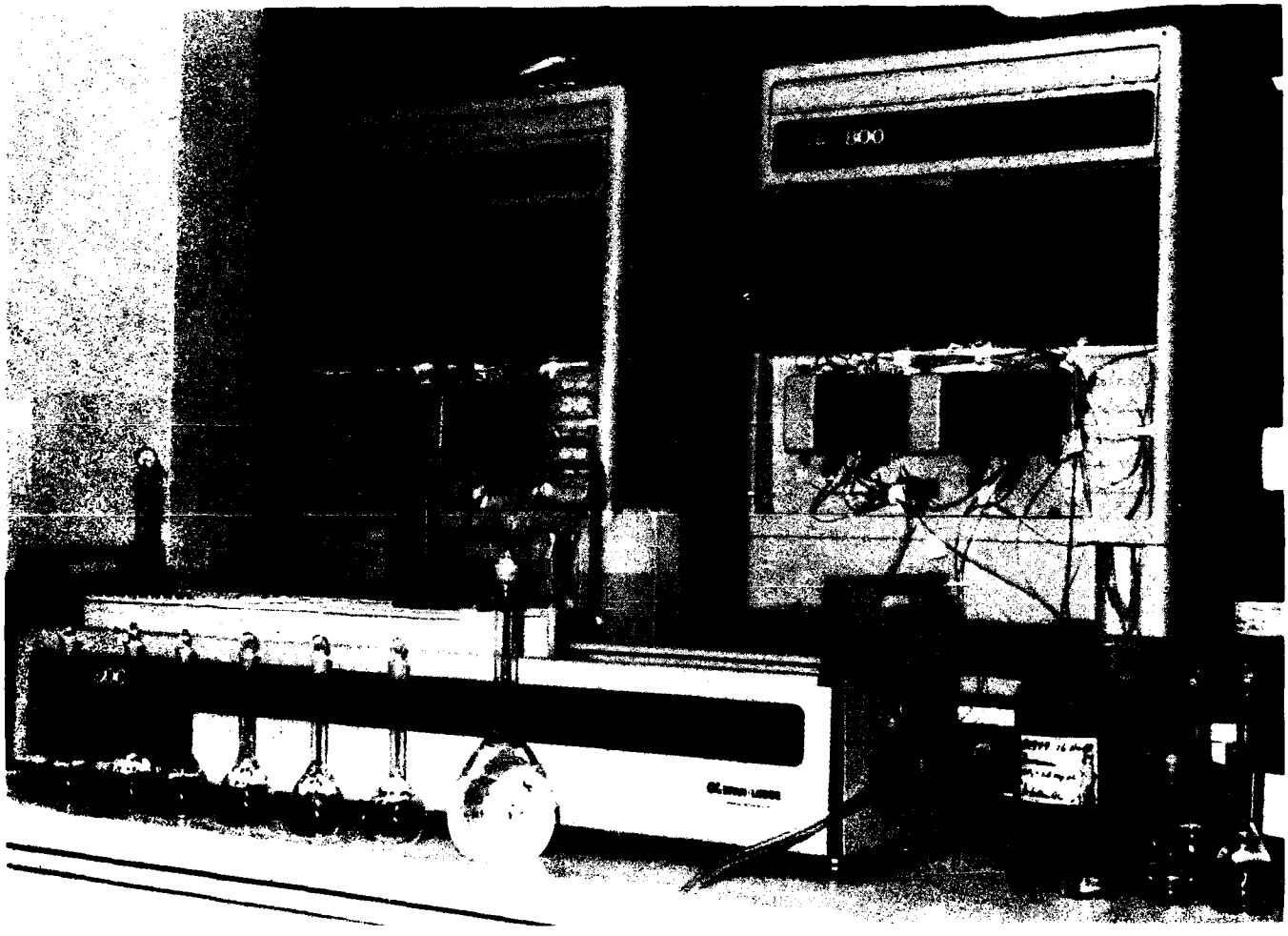

Figure 3. Continuous Flow Analyzer System.

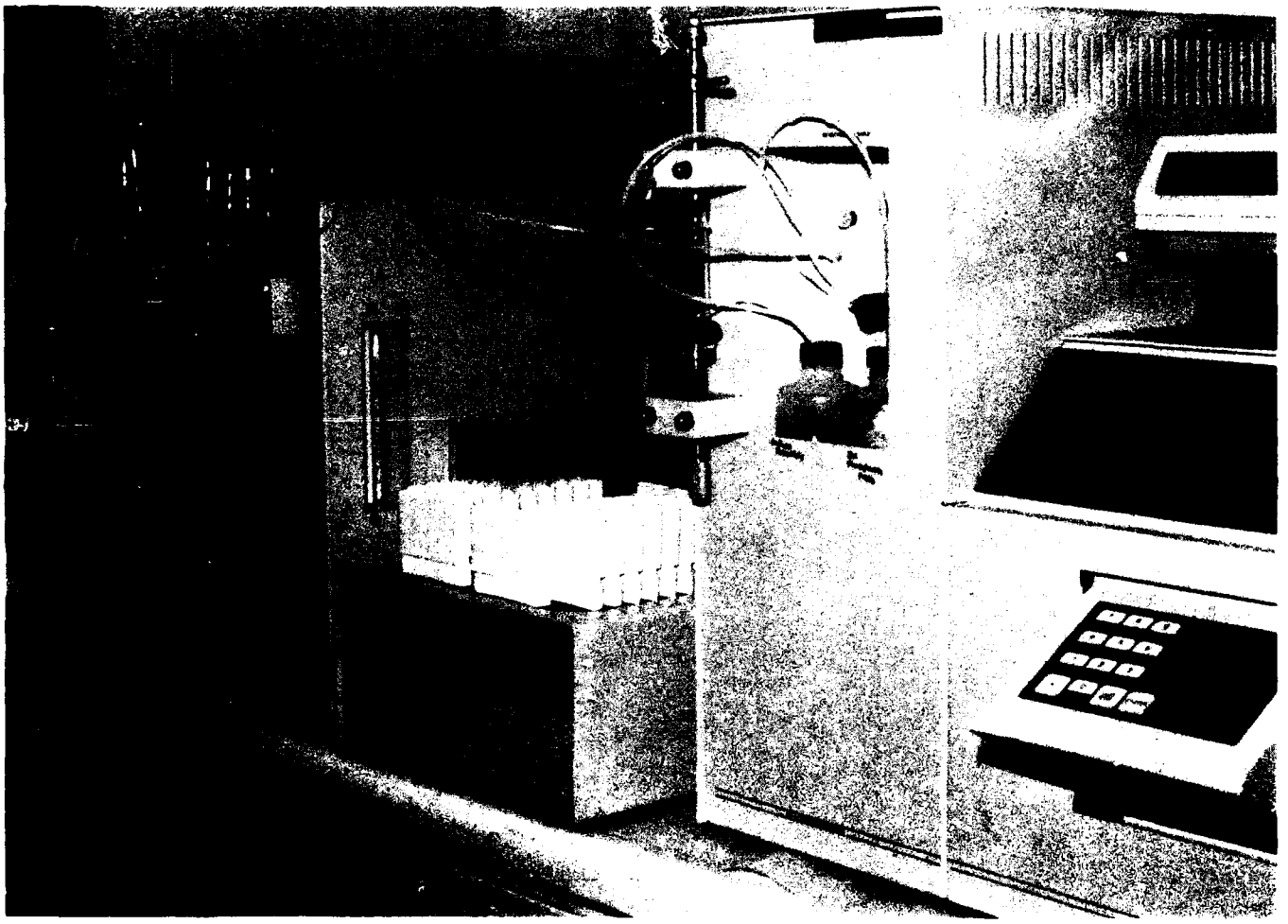

Figure 4. Automated Total Organic Carbon Analyzer.

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APPENDIX F

AUTOMATICALLY GENERATED ANALYTICAL RESULTS

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AIR FORCE
OCCUPATIONAL AND ENVIRONMENTAL HEALTH LABORATORY
BROOKS AFB, TEXAS, 78235-5501

REPORT OF ANALYSIS

BASE SAMPLE NO: GN901027 OEHL SAMPLE NO: 90071417

SAMPLE TYPE: NON-POTABLE WATER

SITE IDENTIFIER: PGX008 DATE RECEIVED: 901130

DATE COLLECTED: 901126 DATE REPORTED: 901217

DATE ANALYZED: 901204

RESULTS

Test	Results	Units
1,3-Dichlorobenzene	<0.9	ug/L
1,4-Dichlorobenzene	<0.7	ug/L
Ethyl Benzene	<0.3	ug/L
Chlorobenzene	<0.6	ug/L
Toluene	<0.3	ug/L
Benzene	<0.5	ug/L
1,2-Dichlorobenzene	<1.0	ug/L

Analytical method used: EPA Method 602

Comments:

< - Signifies none detected and the detection limits.

Analyzed by:

LINDA BISHOP, Sgt, USAF
Volatile Organics Section

Approved by:

George H. Lee, PhD
Chief, Volatile Organics Section

TO:

305 STRATEGIC CLINIC/SGPB
GRISSOM AFB IN 46971-5300

PAGE 1

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APPENDIX G

SAMPLE RECEIPT FORM THAT IS SENT TO CUSTOMERS

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TO: USAF REG HOSP/SGPB
ELMENDORF AFB AK 99506

Your samples were received on 901019 and assigned OEHL sample numbers as follows:

BASE NR.	OEHL NR.	Sample Type
GP900084	90068838	POTABLE WATER
GP900084	90068839	POTABLE WATER
GP900084	90068843	POTABLE WATER
GP900085	90068840	POTABLE WATER
GP900085	90068841	POTABLE WATER

Please refer to the above OEHL sample numbers when calling about your samples. Average processing time is approximately 15 days.

AFOEHL/SA

AFOEHL/SA
BROOKS AFB TX 78235-5501

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

USAF REG HOSP/SGPB
ELMENDORF AFB AK 99506

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APPENDIX H

LABORATORY SAMPLE ANALYSIS MANAGEMENT SYSTEM IN OPERATION AT AFOEHL/SA

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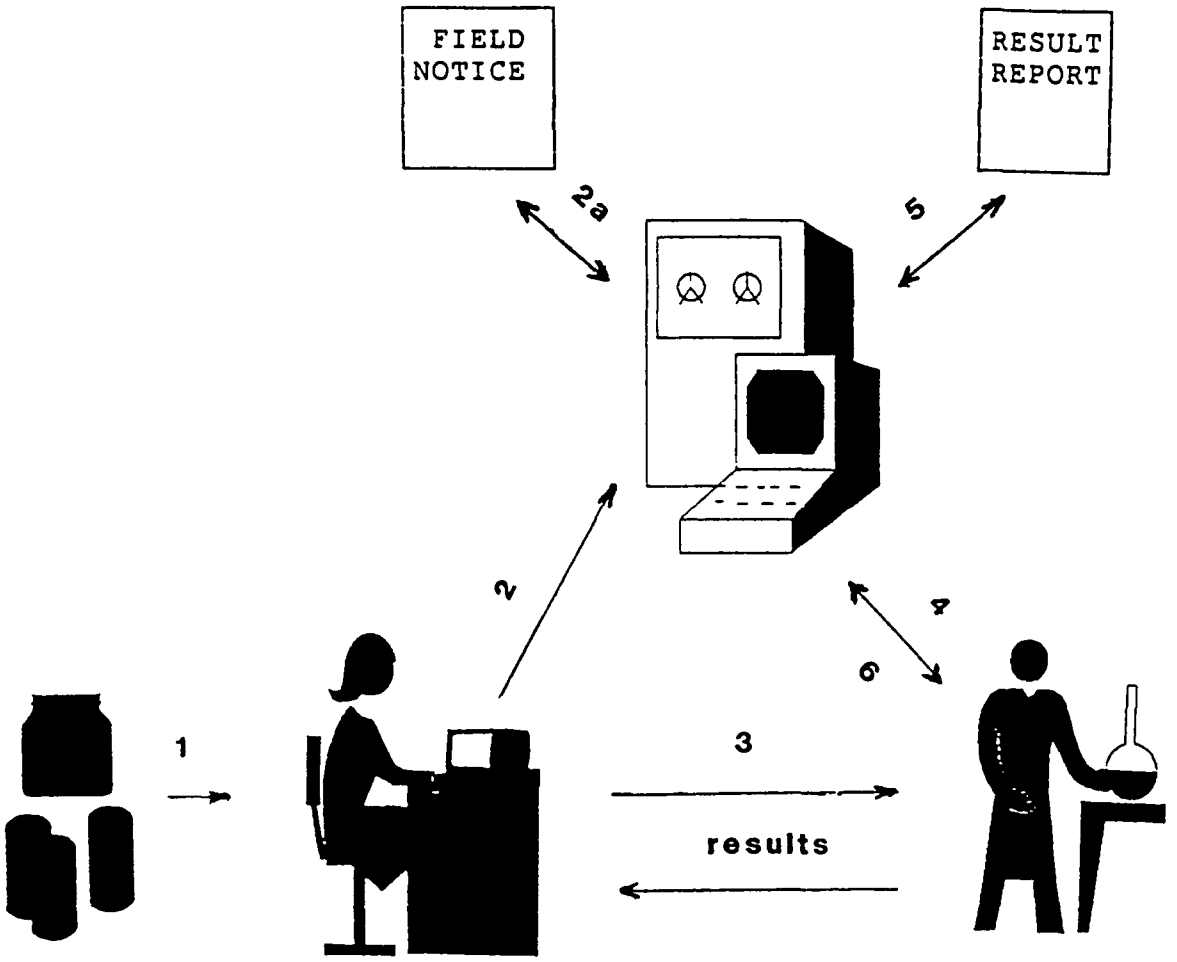

Figure 5. LABSAM Work Flow Chart.

Samples arrive at AFOEHL/SA and are processed by sample control personnel. [1]

Data entry personnel enter information about the sample(which base the sample is from, when was the sample collected/received, what is the base sample identification, etc.) into the sample management data base (LABSAM). [2] A "Field Notice" letting the base know the sample was received, is then generated by LABSAM and mailed the next day. [2a]

The chemist receives the samples for analysis. [3] When the analysis is complete, the chemist gives the results to the data entry personnel. The results are entered into the database [4] and a report is generated from the database. [5]

The chemist also has access to the database to enter or check results or get information about the samples. [6]

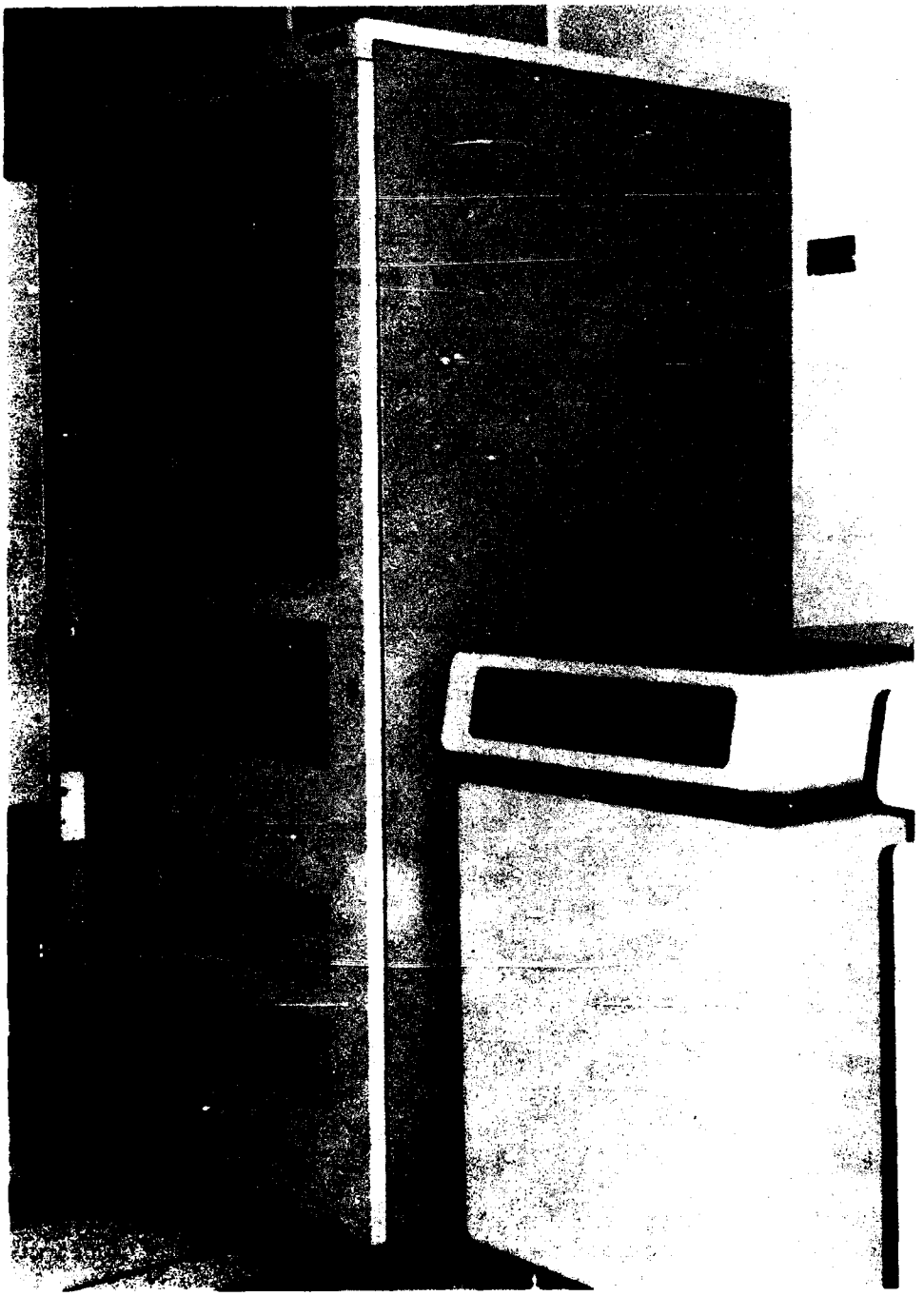

Figure 6. Laboratory Sample Analysis Management System (LABSAM)

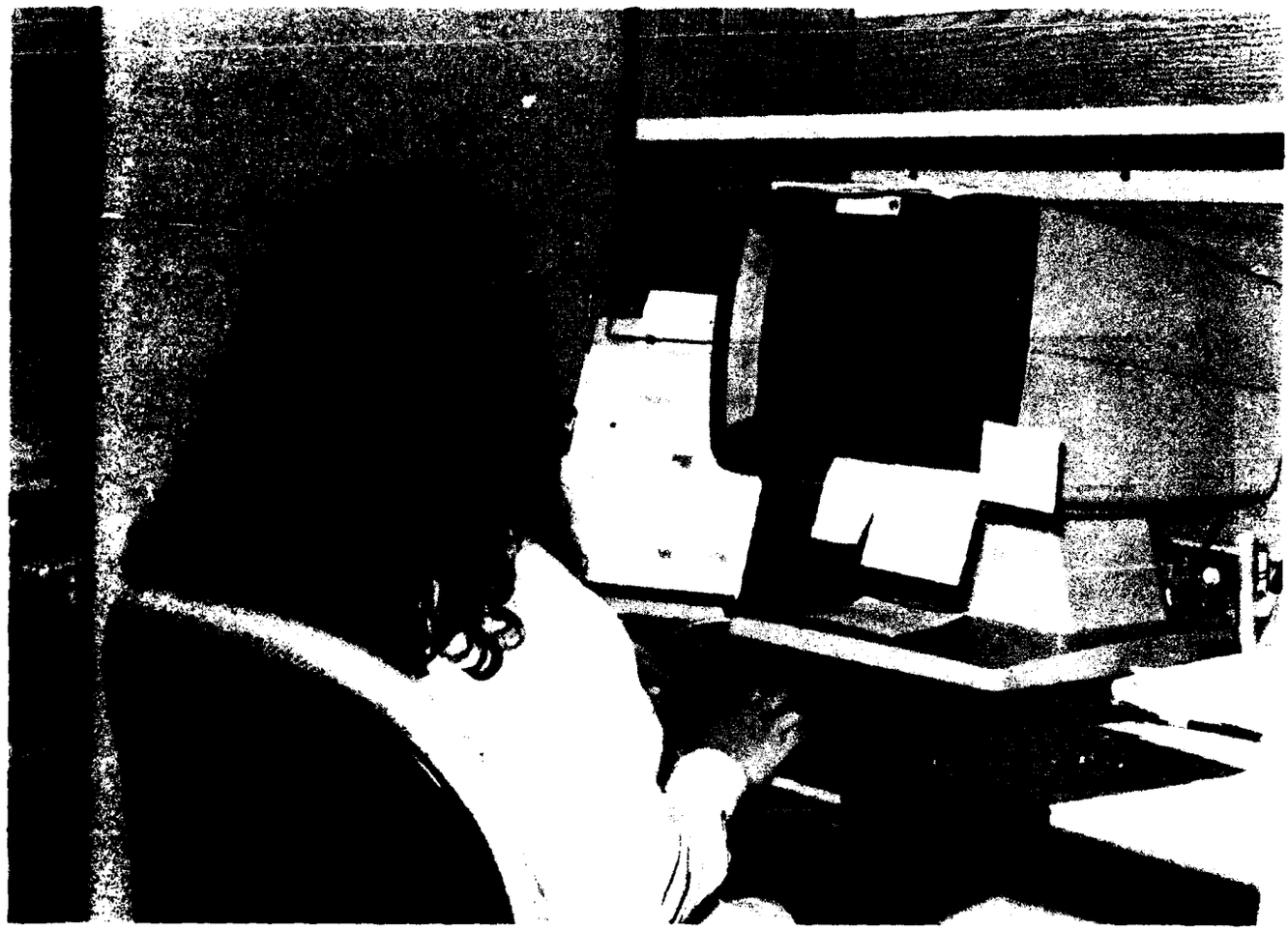

Figure 7. Manual Data Entry into LABSAM.

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APPENDIX I

ANALYST WORKSHEET GENERATED BY LABSAM

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TIME & DATE GENERATED 4 21 PM THU., 6 DEC , 1990 WORKLIST FOR 901206
WORK-CENTER 10132 CHEMICAL OXYGEN DEMAND

OEHL SAMPLE NUMBER	DATE COMP YYMMDD	DATE REC'D YYMMDD	COLLECTED FROM	BASE SAMPLE NUMBER	TESTS REQUESTED TEST	DESCRIPTION	RESULT	UNITS
90072369	352	901206	HOSP WILLIAMS AZ	CN901457	NCOD	Chemical oxygen demand	135	mg/L
90072379		901206	QUALITY ASSURANCE OEHL	GN902581	NCOD	Chemical oxygen demand	<10	mg/L
90072380		901206	QUALITY ASSURANCE OEHL	GN902582	NCOD	Chemical oxygen demand	<10	mg/L
90072381		901206	QUALITY ASSURANCE OEHL	GN902583	NCOD	Chemical oxygen demand	30	mg/L
90072385		901206	HOSP WILLIAMS AZ	CN901442	NCOD	Chemical oxygen demand	135	mg/L
90072389	352	901206	HOSP WILLIAMS AZ	CN901445	NCOD	Chemical oxygen demand	205	mg/L
90072395	353	901206	HOSP WILLIAMS AZ	CN901460	NCOD	Chemical oxygen demand	250	mg/L
90072407	352	901206	93 STRAT HOSP CASTLE CA	GN900679	NCOD	Chemical oxygen demand	<10	mg/L
90072411		901206	93 STRAT HOSP CASTLE CA	GN900680	NCOD	Chemical oxygen demand	25	mg/L
90072415		901206	93 STRAT HOSP CASTLE CA	GN900681	NCOD	Chemical oxygen demand	40	mg/L
90072509	352	901206	22 STRAT HOSP MARCH CA	GP900651	PCOD	Chemical oxygen demand	<10	mg/L

TOTAL OF 11 SAMPLES FOR CHEMICAL OXYGEN DEMAND
ANALYST. REMARKS/STANDARDS.

#58
350

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APPENDIX J

LABSAM MANAGEMENT GENERATED DATA

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REQUESTED PARAMETERS

Date Range	Cmnd.	Base	Type/W.C.	Process	Status	Counts	TTime and Categories YES - YES
901001-901031	ANY	ANY	BRKDN	BRKDN	BRKDN	SAMPLES	
Completed Status					351	(9.9 Days)	
Pending Status					317		
Processed Inhouse						668	
Pending Status					39		
Processed by Transshipment						39	
Air Workcenter Group							714
Completed Status					1	(0.0 Days)	
Processed by Cancellation						1	
Completed Status					505	(3.5 Days)	
Pending Status					8		
Processed Inhouse						513	
Air Particulates Workcenter Group							514
Completed Status					59	(.5 Days)	
Processed by Cancellation						59	
Completed Status					16	(9.8 Days)	
Pending Status					35		
Processed by Direct Shipment						51	
Completed Status					599	(8.9 Days)	
Pending Status					113		
Processed Inhouse						712	
Completed Status					9	(14.7 Days)	
Pending Status					295		
Processed by Transshipment						304	
Trace Org./Pesticide Workcenter Grp							1126
Completed Status					238	(2.9 Days)	
Pending Status					7		
Processed Inhouse						245	
Bulk Asbestos Workcenter Group							245
Completed Status					22	(5.3 Days)	
Processed by Cancellation						22	
Completed Status					5	(13.0 Days)	
Pending Status					21		
Processed by Direct Shipment						26	
Completed Status					335	(11.4 Days)	
Pending Status					213		
Processed Inhouse						548	
Completed Status					4	(15.0 Days)	
Pending Status					2		
Processed by Transshipment						6	
Volatile Organics Workcenter Group							602

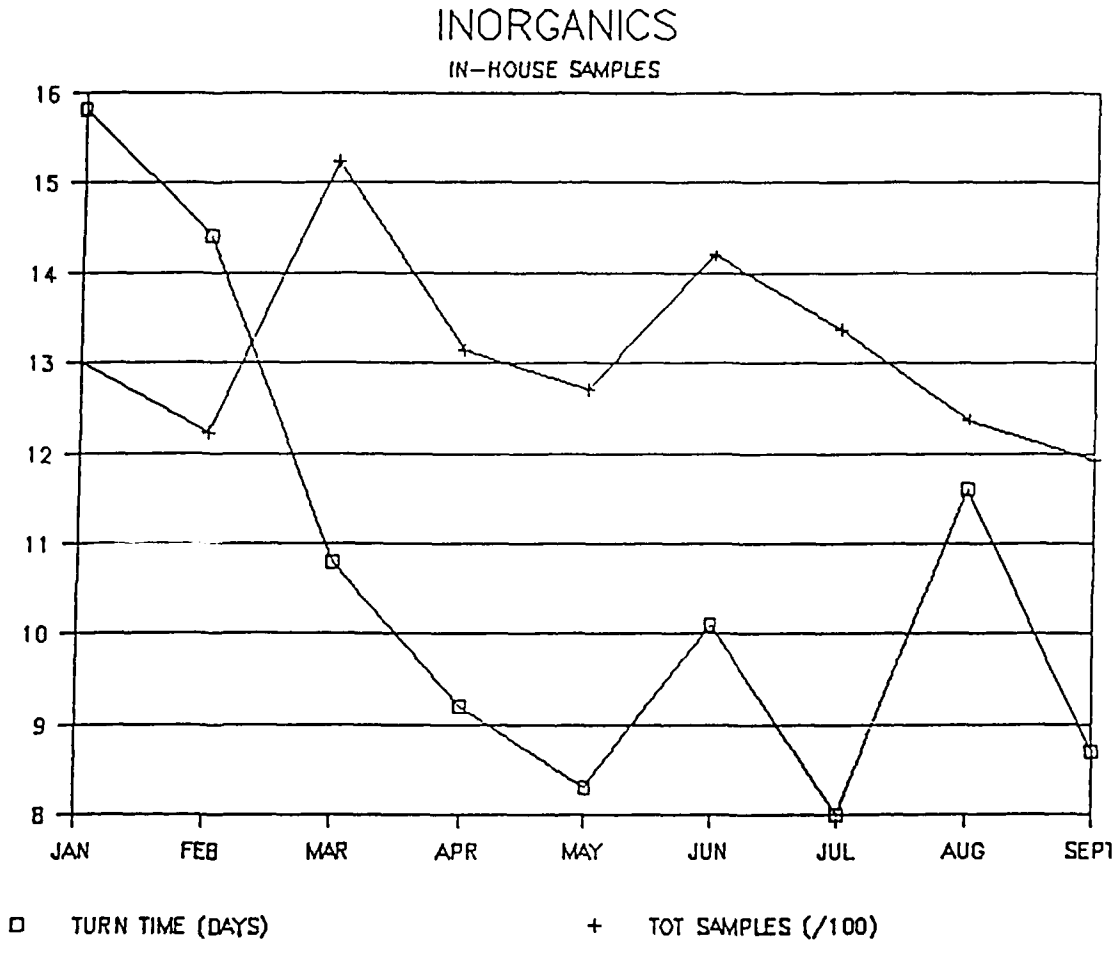

Figure 8. LABSAM Management Data - Inorganic Samples Received.

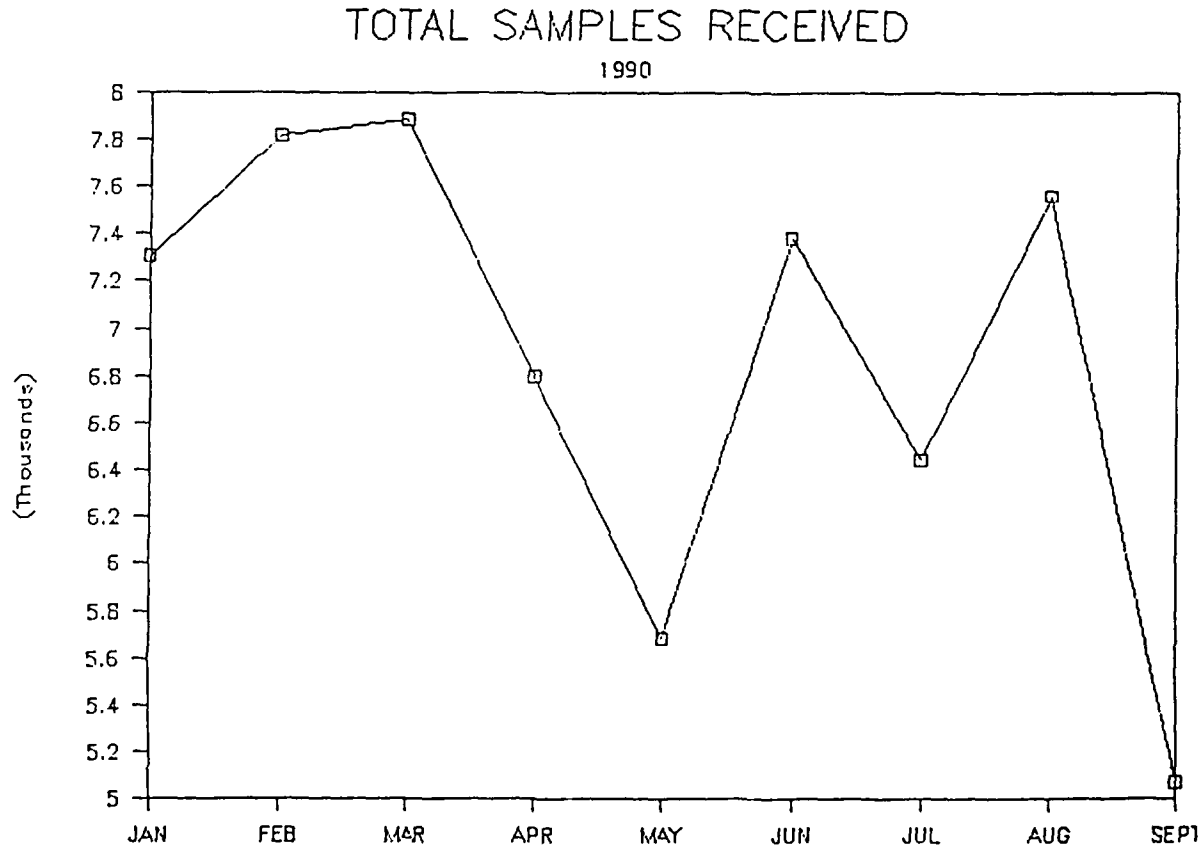

Figure 9. LABSAM Management Data - Total Samples Received.

Report started at: 10:05 AM FRI., 2 NOV., 1990 Page: 1
Report generated by program: NEWCOUNT
Test Request Distribution for OCT 1990 thru OCT 1990
Threshold for this list is 1

Lead	(P743992)	was requested	709 times.
Aroclor 1242	(M5346921)	was requested	571 times.
Aroclor 1254	(M1109769)	was requested	571 times.
Aroclor 1016	(M1267411)	was requested	571 times.
Aroclor 1221	(M1110428)	was requested	571 times.
Aroclor 1232	(M1114116)	was requested	571 times.
Aroclor 1248	(M1267229)	was requested	571 times.
Aroclor 1260	(M1109682)	was requested	571 times.
PCB Screen (total)	(MPCBSCRN)	was requested	571 times.
Asbestos	(A133221)	was requested	437 times.
Oil & Grease	(NOG)	was requested	312 times.
Lead	(N743992)	was requested	265 times.
Asbestos	(M133221)	was requested	246 times.
1,2-Dichlorobenzene	(N9550)	was requested	206 times.
1,4-Dichlorobenzene	(N10646)	was requested	206 times.
Chlorobenzene	(N10890)	was requested	206 times.
1,3-Dichlorobenzene	(N54173)	was requested	206 times.
Trichloroethylene	(N7901)	was requested	196 times.
trans-1,2-Dichloroethene	(N15660)	was requested	183 times.
Chlorodibromomethane	(P12448)	was requested	181 times.
Bromodichloromethane	(P7527)	was requested	181 times.
Chloroform	(P6766)	was requested	181 times.
Bromoform	(P7525)	was requested	181 times.
Cadmium	(N744043)	was requested	176 times.
Chromium	(N744047)	was requested	173 times.
Lead	(T743992)	was requested	170 times.
Cyanide (total)	(N15150)	was requested	169 times.
Silver	(N744022)	was requested	168 times.
Cadmium	(T744043)	was requested	168 times.
Chromium	(T744047)	was requested	167 times.
Trichloroethylene *	(P7901)	was requested	165 times.
Arsenic	(T744038)	was requested	164 times.
Flash Point (closed cup)	(TFPCC)	was requested	151 times.
Mercury	(T743997)	was requested	151 times.
Barium	(T744035)	was requested	150 times.
Selenium	(T778249)	was requested	150 times.
Silver	(T744022)	was requested	150 times.
Ammonia	(N76641)	was requested	149 times.
1,4-Dichlorobenzene *	(P10646)	was requested	148 times.
4-Chlorotoluene	(P10643)	was requested	146 times.
Bromobenzene	(P10886)	was requested	146 times.
Chlorobenzene	(P10890)	was requested	146 times.
1,3-Dichlorobenzene	(P54173)	was requested	146 times.
2-Chlorotoluene	(P9549)	was requested	146 times.
1,2-Dichlorobenzene	(P9550)	was requested	146 times.
Tetrachloroethylene	(P12718)	was requested	145 times.
Chemical oxygen demand	(NCOD)	was requested	143 times.
Phenol	(N10895)	was requested	141 times.
Benzene *	(P7143)	was requested	140 times.
Hydrogen ion (pH)	(TPH)	was requested	139 times.
Corrosivity	(TCOROSIS)	was requested	138 times.
Zinc	(N744066)	was requested	137 times.
trans-1,2-Dichloroethene	(P15660)	was requested	136 times.

APPENDIX K

LABORATORY AUTOMATION SYSTEM AND INSTRUMENTS COUPLED TO IT

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Laboratory Automation System (LAS) is an instrument controller which tells the instrument(s) in which sequence the samples will be analyzed and the parameters to be used (the method) for the analysis. [1]

The instruments pass result data to LAS for calculations. [2]

Data can be passed from LAS to STATIT software for statistical analysis. [3]

Sample results are passed from LAS to the Laboratory Sample Management (LABSAM) database for storage. [4]

LABSAM can automatically schedule samples and create the sequences to be used by LAS. [5]

Sample date is mechanically read from the submission forms and passed to LABSAM for automatic sample log-in. [6]

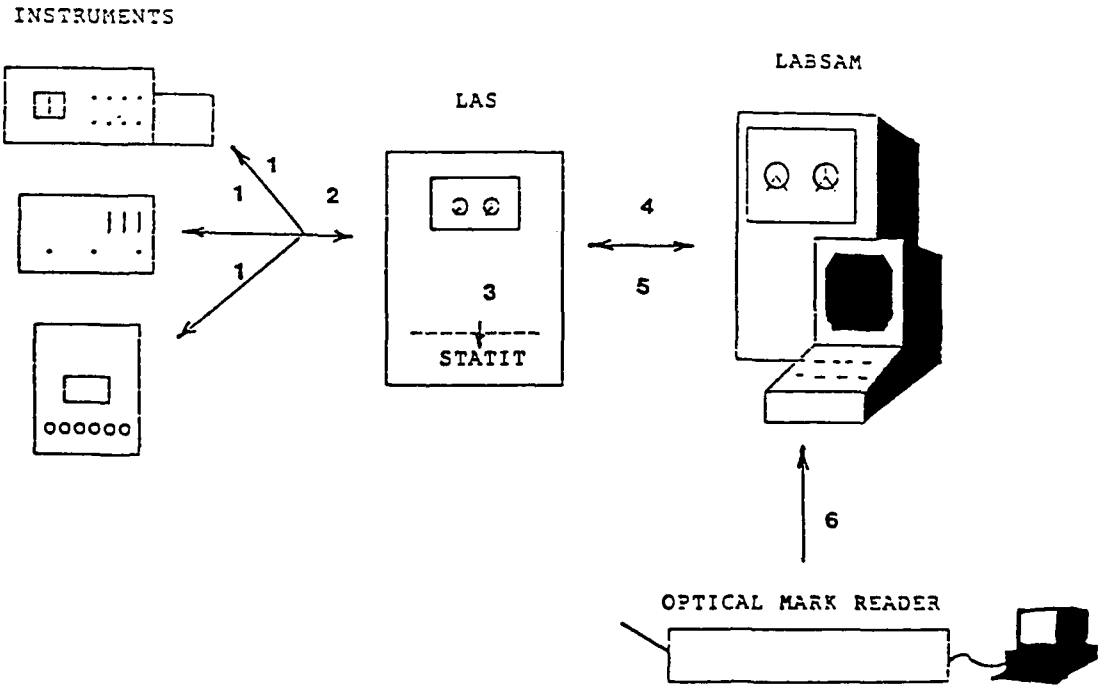

Figure 10. LAS and Instruments Coupled to It.

I. **LABORATORY AUTOMATION SYSTEM**

2- HP A900 COMPUTER SYSTEMS
12- HP TERMINALS
15- HP PRINTERS
STATIT/GRAFIT STATISTICAL/GRAPHING SOFTWARE

II. **LABORATORY SAMPLE MANAGEMENT SYSTEM**

1- HP A900 COMPUTER SYSTEM
21- HP TERMINALS
8- HP PRINTERS
1- OPTICAL MARK READER SYSTEM WITH PC INTERFACE

III. **ANALYTICAL INSTRUMENTION**

INDUSTRIAL HYGIENE ANALYSIS FUNCTION:

13- GAS CHROMATOGRAPHS WITH AUTOSAMPLERS
1- ION CHROMATOGRAPH WITH AUTO SAMPLER
3- HIGH PRESSURE LIQUID CHROMATOGRAPHS WITH AUTO SAMPLERS
1- ZYMARK ROBOTIC SYSTEM TO PREPARE IH SAMPLES
1- HGA ATOMIC ABSORPTION SPECTROMETER WITH AUTO SAMPLER
1- ICP SPECTROMETER WITH AUTO SAMPLER
MULTIPLE A/D CONVERTERS/PRINTERS/PC CONTROLS

INORGANICS ANALYSIS FUNCTION:

10- AUTOANALYZER II SYSTEMS
1- CONTINUOUS FLOW ANALYZER SYSTEM
1- TOC ANALYZER WITH AUTO SAMPLER
1- ION CHROMATOGRAPH WITH AUTO SAMPLER
1- FLAME ATOMIC ABSORPTION SPECTROMETER WITH AUTO SAMPLER
2- HGA ATOMIC ABSORPTION SPECTROMETER WITH AUTO SAMPLER
1- ZYMARK ROBOTIC MERCURY SAMPLE PREPARATION AND ANALYSIS SYSTEM
MULTIPLE A/D CONVERTERS/PRINTERS/PC CONTROLS

VOLATILE SOLVENT ANALYSIS FUNCTION:

13- PURGING TRAP GC SYSTEM WITH AUTO SAMPLERS
MULTIPLE A/D CONVERTERS/PRINTERS/PC CONTROLS

PESTICIDE AND TRACE ORGANIC ANALYSES FUNCTION:

15- GAS CHROMATOGRAPHS WITH AUTO SAMPLERS
1- ZYMARK ROBOTIC PCB SAMPLE PREPARATION SYSTEM
4- HIGH PRESSURE LIQUID CHROMATOGRAPHS WITH AUTO SAMPLERS
MULTIPLE A/D CONVERTERS/PRINTERS/PC CONTROLS

Figure 11. Laboratory Automation System.

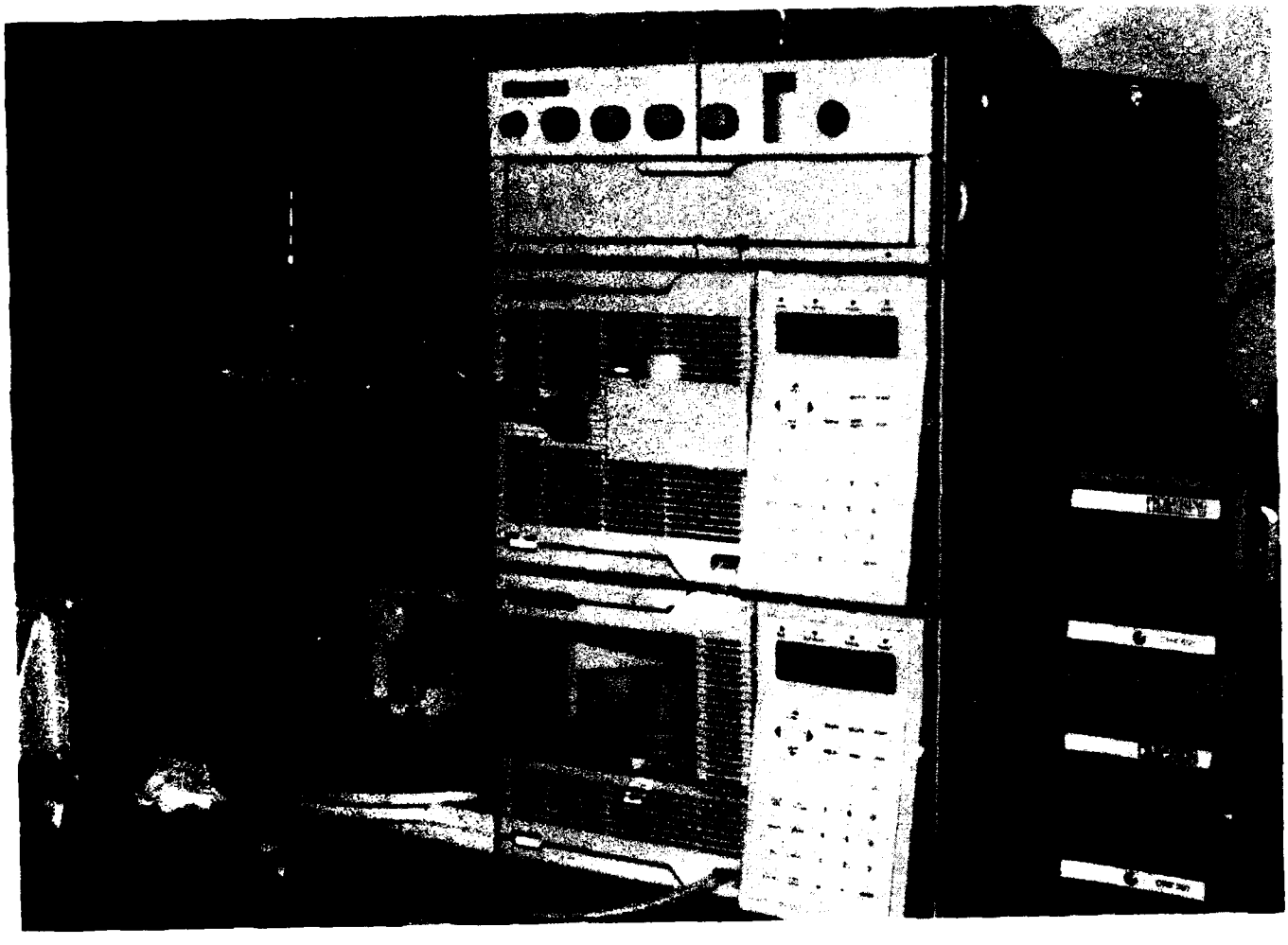

Figure 12. Liquid Chromatograph and Robotic Sampler.

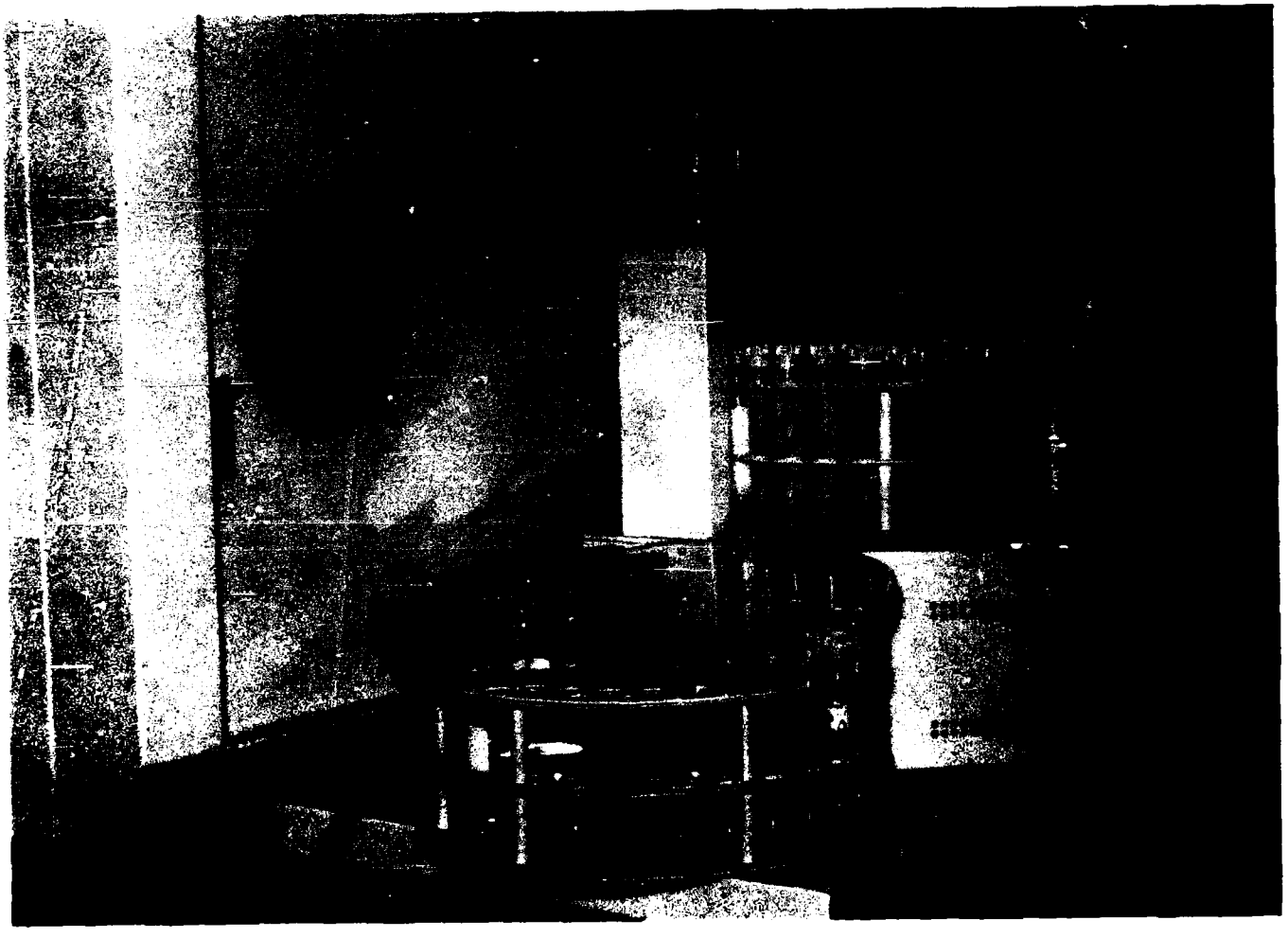

Figure 13. Inductively Coupled Plasma Analyzer and Automated Sampler System.

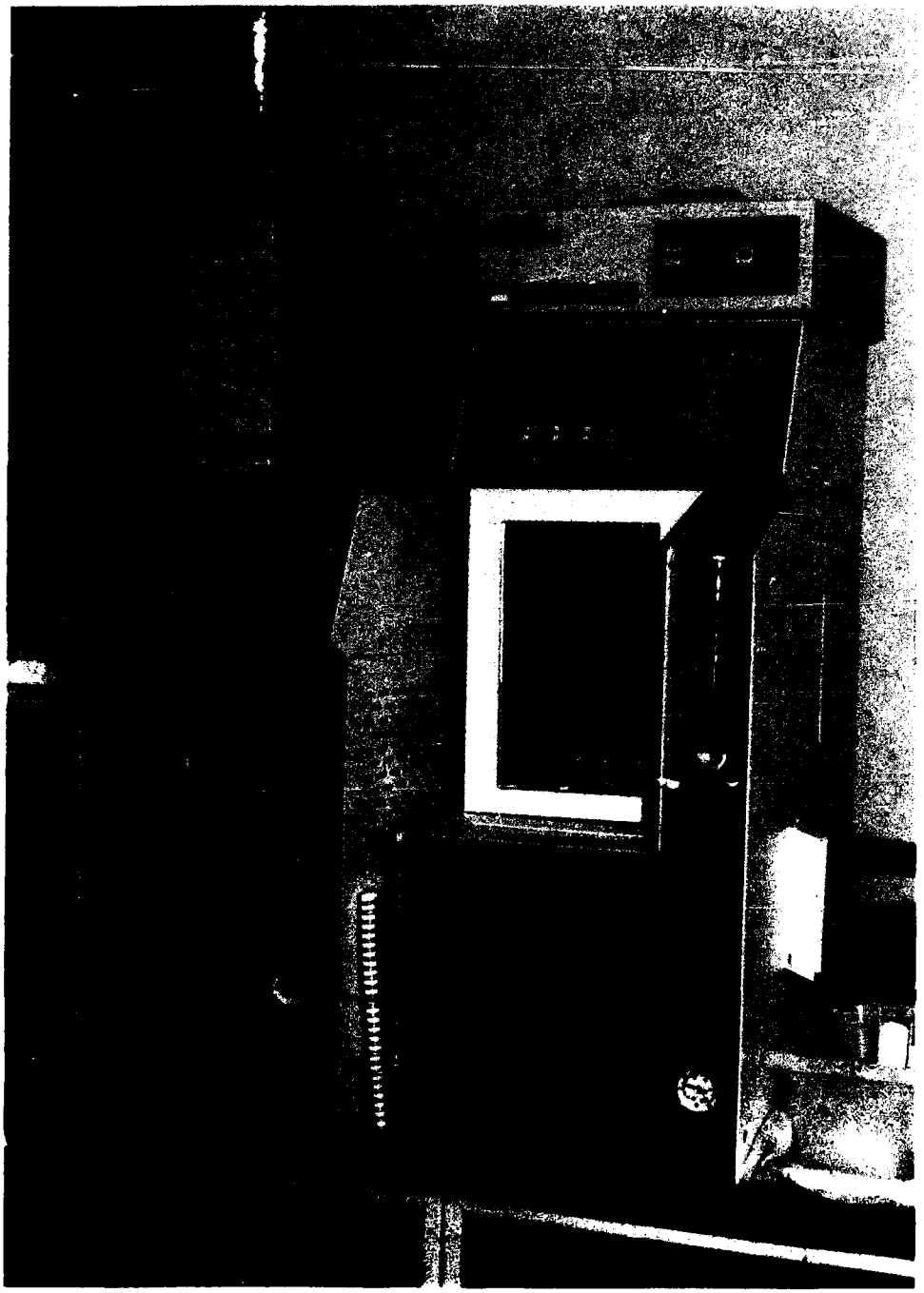

Figure 14. Purging Trap Gas Chromatograph and Automated Sample Bottle Accessory.

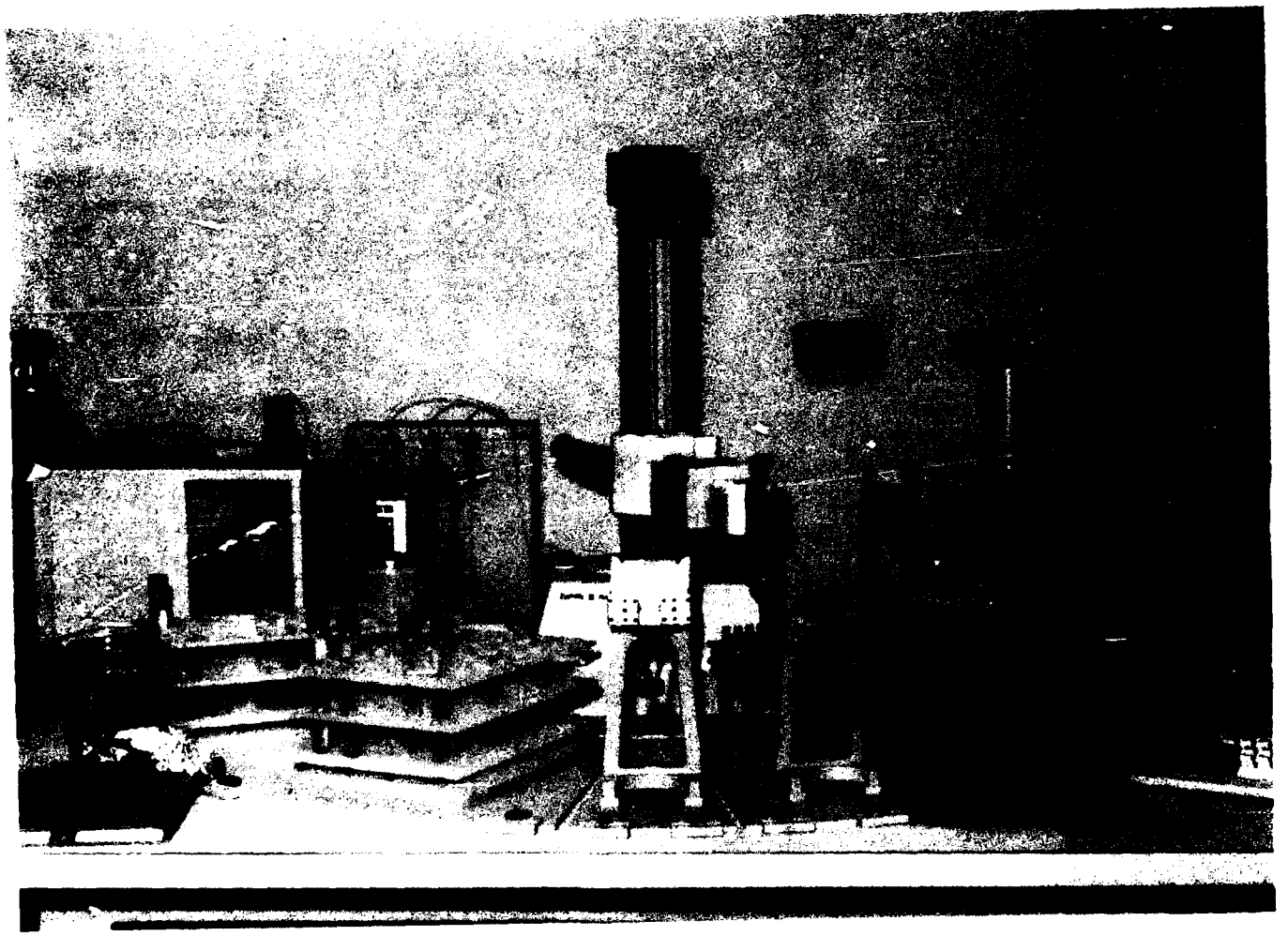

Figure 15. PCB Robotic Sample Preparation System.

Figure 16. IH Charcoal Tube Robotic Sample Preparation System.

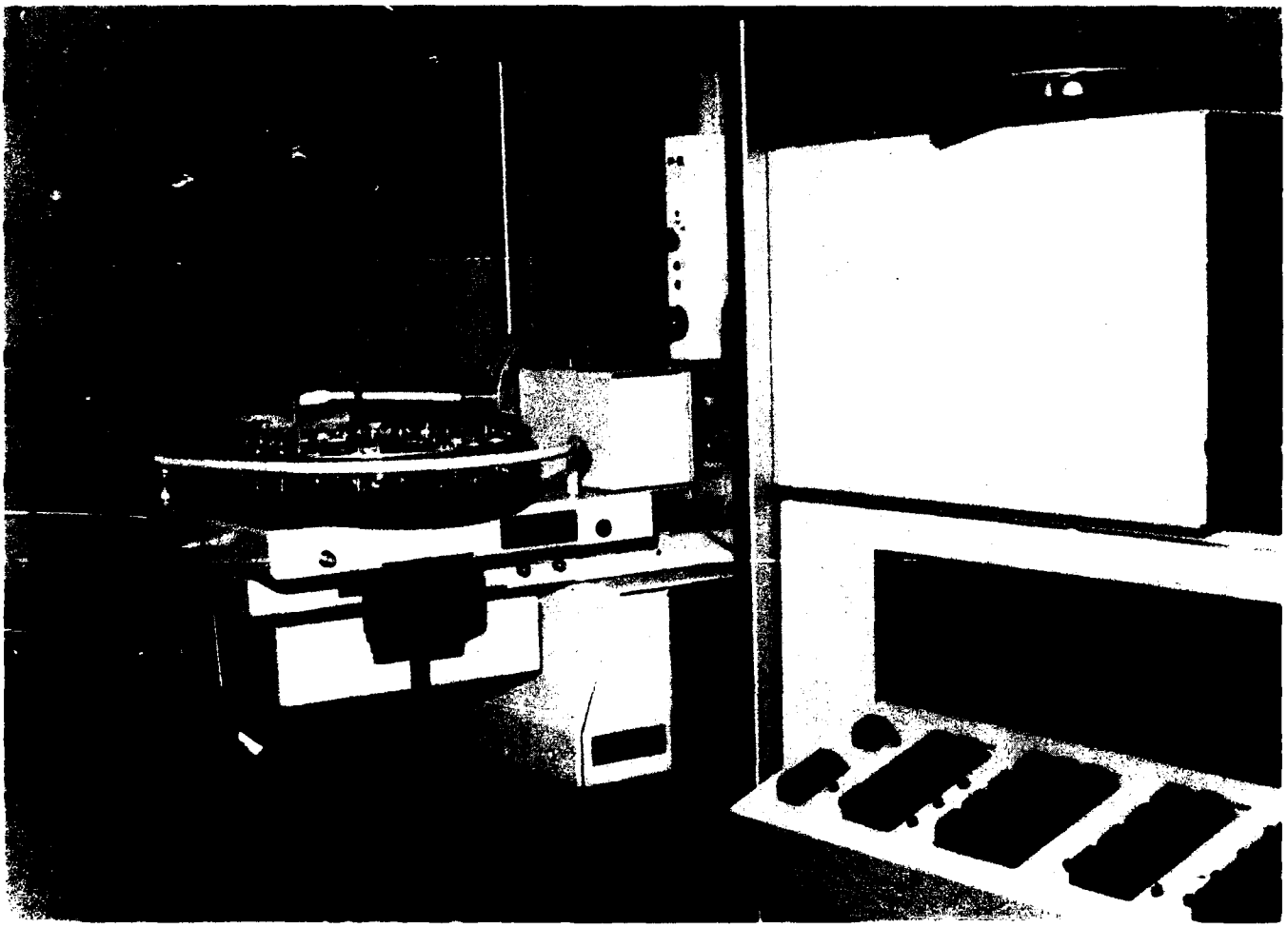

Figure 17. Heated Graphite Furnace/Atomic Absorption System with Automated Sampler.

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APPENDIX L

LAS DATA AND STATISTICAL PRINTOUTS

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REPORT: 651.41 CHANNEL: 27 EPA531.1 SPERISORB ODS2

SAMPLE: CRB65114 INJECTED AT 11:19:23 ON NOV 7, 1990

ESTD METHOD: CARB27 SEQ: *SEQ27 SUBSQ/SAMP: 1/ 1

SL-WDTH	MV/MIN	DELAY	MIN-AR	BUNCH
.500	.100	15.00	25000	AUTO

SUP-UNK	DVT	ID-LVL	REF-RTW	%RTW	%DIL-F	I
NO	0.00	45000	.200	5.000	100.00	YES

ACTUAL RUN TIME: 45.508 MINUTES

ENDED NOT ON BL

RT	ITM	FACTOR	AREA		UG/L	NAME
18.60	18.60#	2.0631E- 5	1259134	VV	25.977	#ALD SULFX
19.03	19.03#	1.4850E- 5	844937	VV	12.548	#ALD SULFN
20.01	20.01#	2.3862E- 5	613570	VV	14.641	#OXAMYL
21.65	21.28	1.2812E- 5	600443	VV	7.693	#METHOMYL
25.05	25.05#	2.1081E- 5	200675	VV	4.230	##3-HYDROXYCARBOFURAN
25.93		1.0000E+ 0	33161	VV	33161.5	
28.94	28.94#	1.9572E- 5	492512	VV	9.639	#ALDICARB
31.34	31.34#	1.2522E- 5	720052	VV	9.017	#CARBOFURAN
35.72		1.0000E+ 0	43431	VV	43430.7	
43.68		1.0000E+ 0	181874	VF	181874.	

TOTAL AREA = 4989792 TOTAL UG/L = 258550.871

PROCESSED DATA FILE: P65114 RAW DATA FILE: R65114

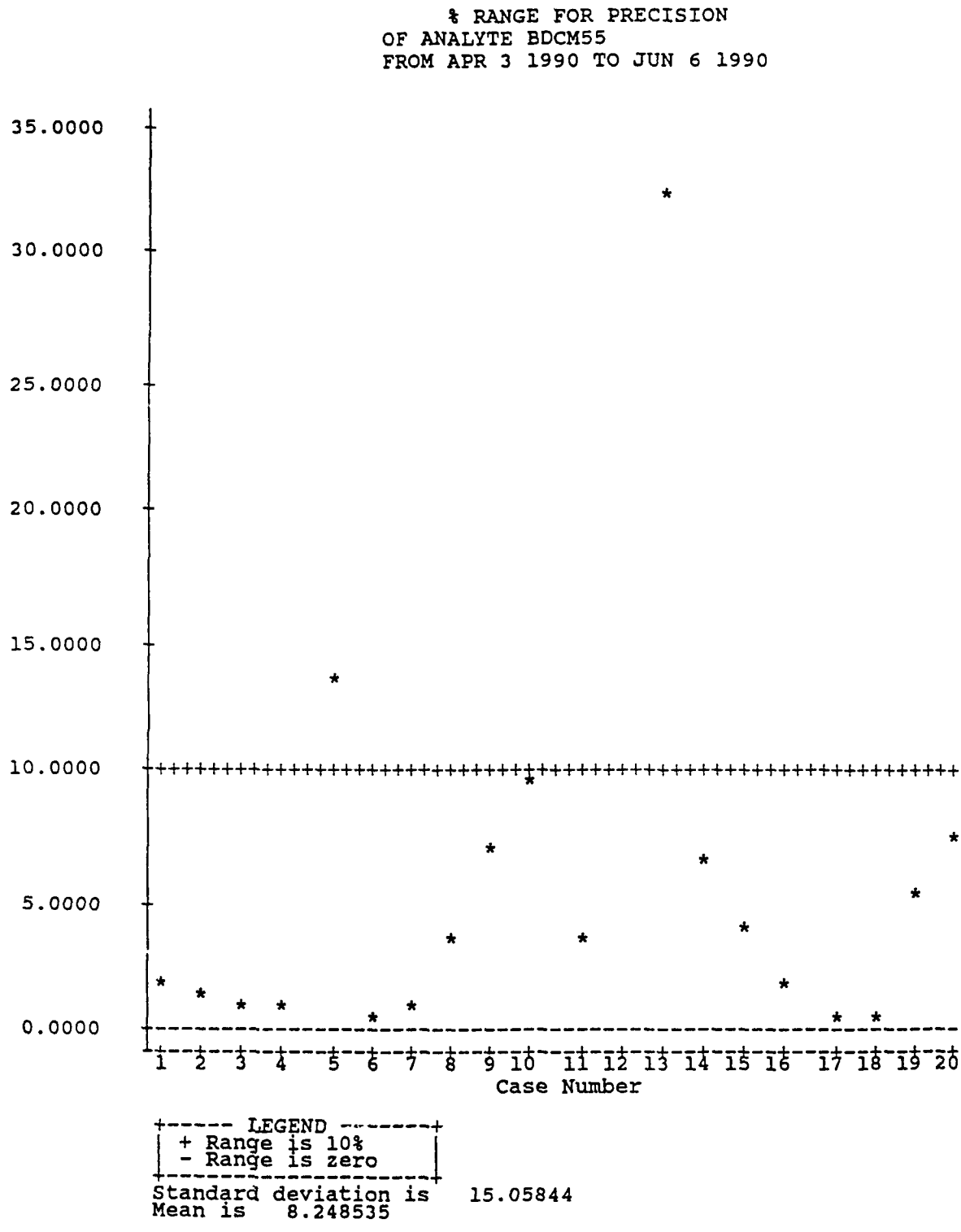

Figure 18. LAS QA Precision on Analysis - Statistical Printout

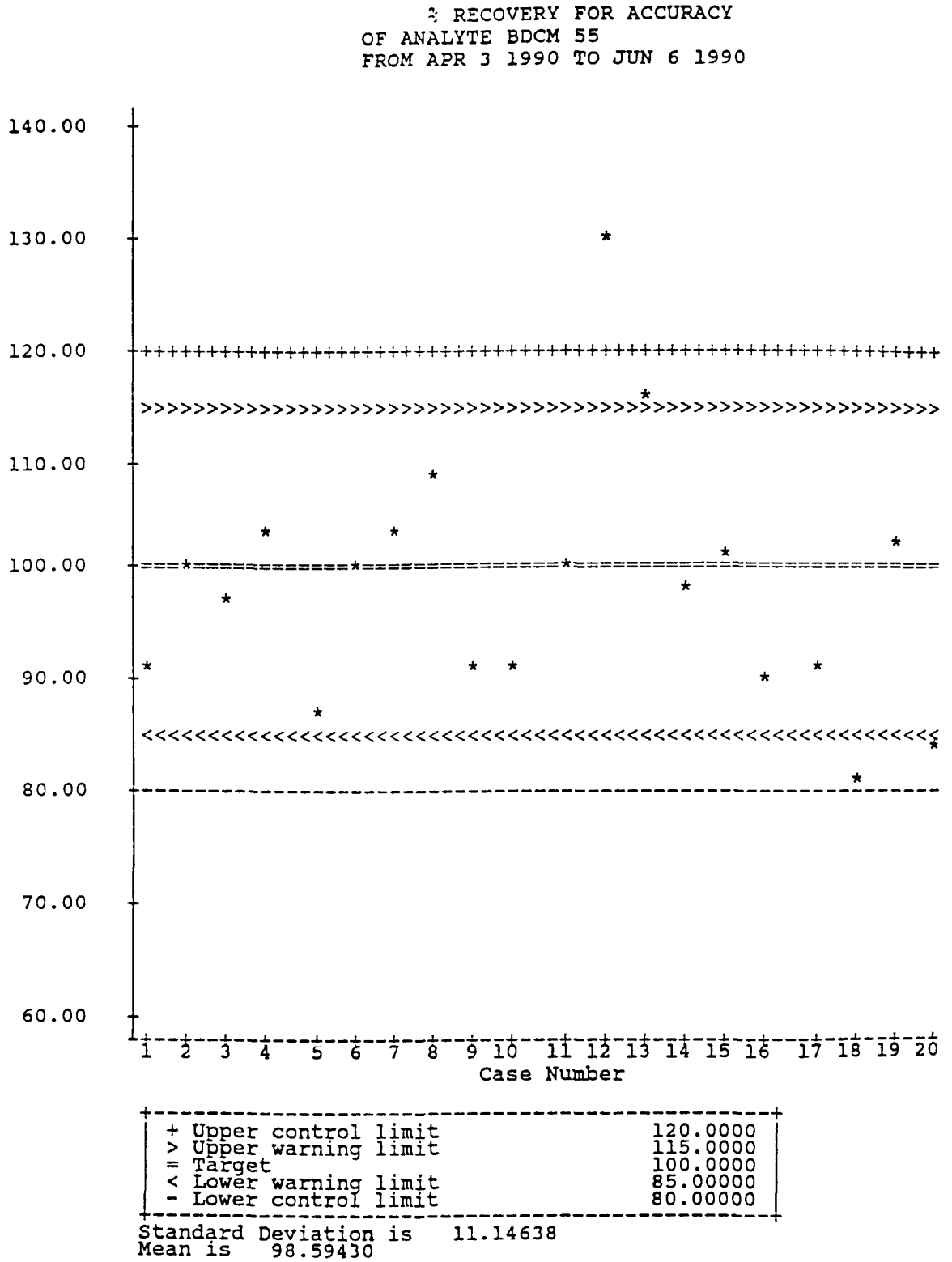

Figure 19. LAS QA Accuracy on Analysis - Statistical Printout

Calculations for data from file BDCM55.VDAT

Obs	DATE	ACTUAL	VALUE1	VALUE2	VALUE3	RETIME1	RETIME2	RETIME3	AVGVALUI
1	03APR1990	7.000	6.371	6.484	6.198	22.65	22.66	22.65	6.428
2	03APR1990	11.700	11.780	11.622	10.895	22.65	22.64	22.67	11.701
3	03APR1990	23.400	22.851	22.636	22.334	22.63	22.64	22.62	22.744
4	04APR1990	11.700	12.090	12.214	?	22.66	22.63	?	12.152
5	09APR1990	7.000	6.524	5.678	5.472	22.63	22.61	22.63	6.101
6	09APR1990	11.700	11.736	11.699	11.665	22.59	22.60	22.62	11.718
7	10APR1990	23.400	24.068	24.241	24.410	22.57	22.61	22.56	24.155
8	10APR1990	11.700	12.499	12.977	?	22.56	22.60	?	12.738
9	11APR1990	11.700	10.363	11.104	?	22.63	22.60	?	10.734
10	12APR1990	11.700	10.166	11.194	?	22.59	22.57	?	10.680
11	13APR1990	11.700	11.535	11.928	?	22.57	22.57	?	11.732
12	16APR1990	11.700	20.105	10.334	?	22.53	22.57	?	15.219
13	17APR1990	11.700	11.379	15.760	?	22.53	22.56	?	13.569
14	18APR1990	11.700	11.200	11.947	?	22.53	22.57	?	11.574
15	19APR1990	11.700	12.073	11.619	?	22.54	22.53	?	11.846
16	20APR1990	19.700	17.654	17.932	?	22.51	22.55	?	17.793
17	04JUN1990	10.300	9.421	9.443	?	22.17	22.17	?	9.432
18	05JUN1990	10.300	8.428	8.403	7.685	22.17	22.17	22.17	8.416
19	06JUN1990	19.700	20.634	19.608	?	22.10	22.10	?	20.121
20	06JUN1990	10.300	8.366	9.009	8.180	22.10	22.12	22.11	8.688

Obs	AVGRETIME	RANGE	RECOV1	RECOV2	AVGRECOV
1	22.66	1.7581	91.01	92.63	91.82
2	22.65	1.3503	100.68	99.33	100.01
3	22.64	0.9453	97.65	96.74	97.19
4	22.65	1.0204	103.33	104.39	103.86
5	22.62	13.8666	93.20	81.11	87.16
6	22.60	0.3158	100.31	99.99	100.15
7	22.59	0.7162	102.85	103.59	103.22
8	22.58	3.7525	106.83	110.91	108.87
9	22.62	6.9036	88.57	94.91	91.74
10	22.58	9.6255	86.89	95.68	91.28
11	22.57	3.3500	98.59	101.95	100.27
12	22.55	64.2005	171.84	88.32	130.08
13	22.55	32.2856	97.26	134.70	115.98
14	22.55	6.4544	95.73	102.11	98.92
15	22.53	3.8325	103.19	99.31	101.25
16	22.53	1.5624	89.61	91.03	90.32
17	22.17	0.2333	91.47	91.68	91.57
18	22.17	0.2971	81.83	81.58	81.70
19	22.10	5.0991	104.74	99.53	102.14
20	22.11	7.4015	81.22	87.47	84.34

Methods for calculating data from file BDCM55.VDAT

AVGVALUE=(VALUE1+VALUE2)/2

AVGRETIME = (RETIME1+RETIME2)/2

RANGE=(ABS(VALUE1-VALUE2)/AVGVALUE)*100

RECOV1=(VALUE1/ACTUAL)*100

RECOV2=(VALUE2/ACTUAL)*100

AVGRECOV=(AVGVALUE/ACTUAL)*100

APPENDIX M

EXAMPLE OF AUTOMATED SAMPLE DATA ENTRY BUBBLE FORM

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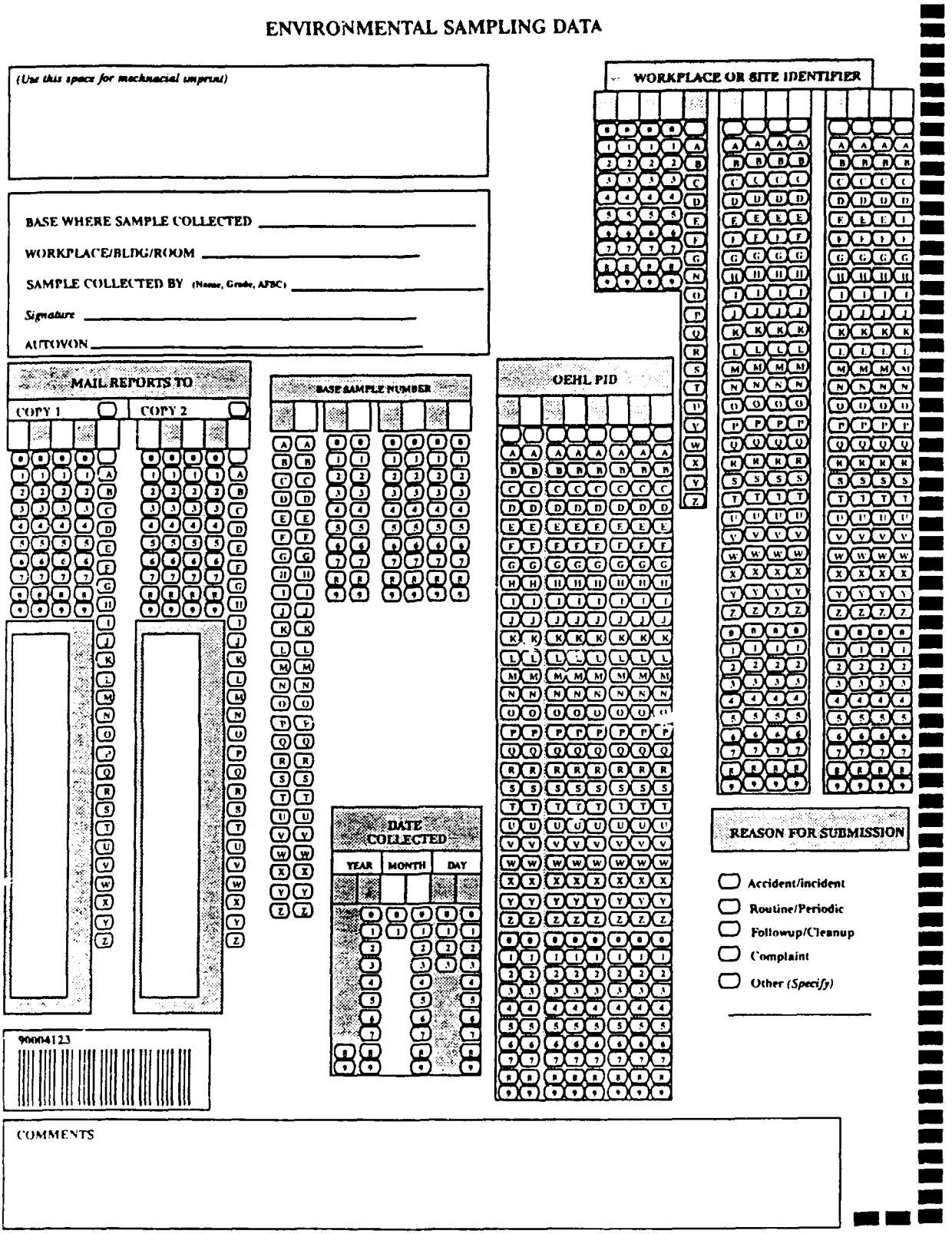
ENVIRONMENTAL SAMPLING DATA



ENVIRONMENTAL SAMPLING DATA

- ☐ EPA 501.1 Total trihalomethanes
- ☐ EPA 502.1 Volatile Halocarbons
- ☐ EPA 502.2 Volatile aromatics
- ☐ EPA 503.1 Aromatic Chem. indicators
- ☐ EPA 510.1 Max. Trihalomethane potential
- ☐ EPA 601 Volatile Halocarbons
- ☐ EPA 602 Volatile aromatics
- ☐ 8010 Halogenated volatile organics
- ☐ 8015 Non-halo. volatile organics
- ☐ 8020 Aromatic volatile organics

- ☐ EPA 524.1 Vol. Aro. & unsat. Org. Cmpds.
- ☐ EPA 624 Volatile organics
- ☐ 8080 Organochlorine pest. & PCBs
- ☐ 8240 EDB & DBCP
- ☐ 8250
- ☐ 8270

- ☐ EPA 606 Phthalate esters
- ☐ Total organic halides
- ☐ PCB screen

- ☐ EPA 504 EDB & DBCP
- ☐ EPA 505 Organohalide pest./PCBs
- ☐ EPA 507 Organo pesticides
- ☐ EPA 515.1 Organo pesticides
- ☐ EPA 531 Methylcarbamates
- ☐ EPA 608 Organochloride pest./PCBs
- ☐ EPA 615 Chlorinated pesticides
- ☐ 8080
- ☐ 8140 Oragnophosphorous pest.
- ☐ 8150 Chlorinated herbicides
- ☐ Hazardous pesticides

OTHER

- ☐ _____
- ☐ _____
- ☐ _____

GROUP A
- ☐ Chem. oxygen demand
- ☐ Organic carbon

GROUP B
- ☐ Oil & grease

GROUP C
- ☐ Ammonia
- ☐ Nitrate
- ☐ Nitrite
- ☐ Kjeldahl nitrogen
- ☐ Orthophosphate
- ☐ Phosphorus

GROUP F
- ☐ Antimony
- ☐ Arsenic
- ☐ Barium
- ☐ Beryllium
- ☐ Cadmium
- ☐ Calcium
- ☐ Chromium, total
- ☐ Chromium VI
- ☐ Copper
- ☐ Iron
- ☐ Lead
- ☐ Magnesium
- ☐ Manganese
- ☐ Mercury
- ☐ Nickel
- ☐ Potassium
- ☐ Selenium
- ☐ Silver
- ☐ Sodium
- ☐ Thallium
- ☐ Zinc

GROUP D
- ☐ Cyanide, total
- ☐ Cyanide, free

GROUP E
- ☐ Phenols

GROUP H
- ☐ Aldrin
- ☐ BHC Isomers
- ☐ a-BHC
- ☐ b-BHC
- ☐ d-BHC
- ☐ Carbamates
- ☐ Chlordane
- ☐ DBCP
- ☐ DDT Isomers
- ☐ p,p-DDD
- ☐ p,p-DDE
- ☐ p,p-DDT
- ☐ Diazanon
- ☐ Dieldrin
- ☐ Duraban
- ☐ EDB
- ☐ Endrin
- ☐ Heptachlor
- ☐ Hept. epoxide
- ☐ Lindane
- ☐ Malathion
- ☐ Methoxychlor
- ☐ Pramitol
- ☐ Silvex
- ☐ Toxaphene
- ☐ 2,4-D
- ☐ 2,4,5-T

GROUP J
- ☐ Sulfides

GROUP G
- ☐ Acidity, total
- ☐ Alkalinity, total
- ☐ Alkalinity, bicarb
- ☐ Boron
- ☐ Bromide
- ☐ Carbon Dioxide
- ☐ Chloride
- ☐ Color
- ☐ Fluoride
- ☐ Hardness
- ☐ Residue, total
- ☐ Residue, filterable
- ☐ Residue, nonfilterable
- ☐ Residue, settleable
- ☐ Residue, volatile
- ☐ Silica
- ☐ Specific Conductance
- ☐ Sulfate
- ☐ Surfactants
- ☐ Turbidity

OTHER

- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____

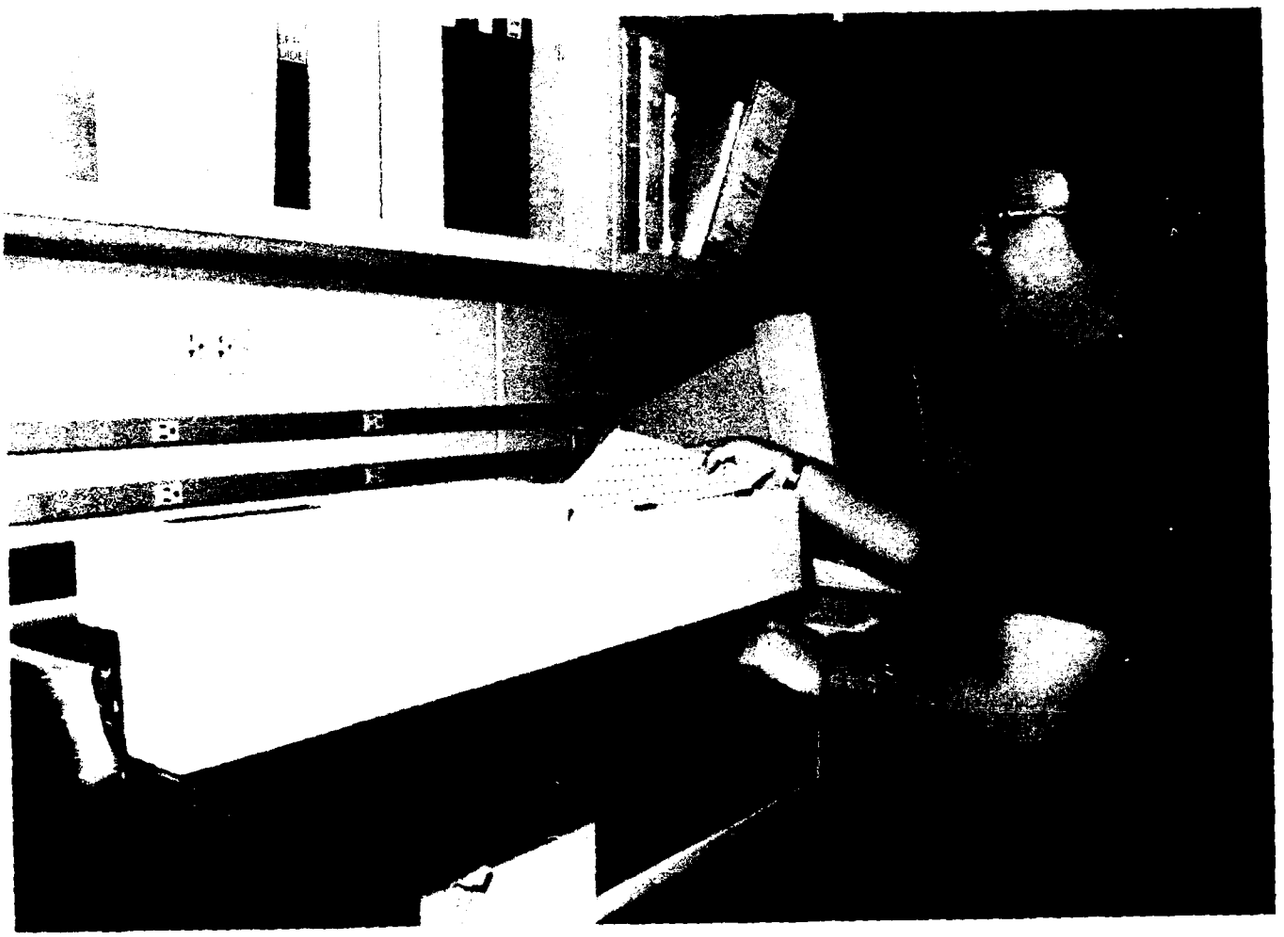


Figure 20. Automated Sample Data Entry System.

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Distribution List

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